University of Alberta Library
0 1620 2666555 2

Ex libris
universitatis
albertaensis

BRUCE PEEL SPECIAL COLLECTIONS LIBRARY

UNIVERSITY OF ALBERTA

**REQUEST FOR DUPLICATION**

I wish a photocopy of the thesis by Normand Lucien Cool

entitled Physiological indices of winter condition of wapiti and Moose. (M.Sc.)

The copy is for the sole purpose of private scholarly or scientific study and research. I will not reproduce, sell or distribute the copy I request, and I will not copy any substantial part of it in my own work without permission of the copyright owner. I understand that the Library performs the service of copying at my request, and I assume all copyright responsibility for the item requested.

[redacted]

Pages copied _____

Date _____ Signature _____

Name and address _____

Pages copied _____

Date _____ Signature _____

Name and address _____

Pages copied _____

Date _____ Signature _____

Name and address _____

Pages copied _____

Date _____ Signature _____

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: NORMAND LUCIEN COOL

TITLE OF THESIS: PHYSIOLOGICAL INDICES OF WINTER CONDITION OF WAPITI AND MOOSE

DEGREE: MASTER OF SCIENCE

YEAR THIS DEGREE GRANTED: SPRING 1992

Permission is hereby granted to the University of Alberta library to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

The author reserves all other publication and other rights in association with the copyright in the thesis, and except as hereinbefore provided neither the thesis nor any substantial portion thereof may be printed or otherwise reproduced in any material form whatever without the author's prior written permission.

[redacted]

UNIVERSITY OF ALBERTA

# PHYSIOLOGICAL INDICES OF WINTER CONDITION OF WAPITI AND MOOSE

by

NORMAND LUCIEN COOL

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

WILDLIFE PRODUCTIVITY AND MANAGEMENT

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

SPRING 1992

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled PHYSIOLOGICAL INDICES OF WINTER CONDITION OF WAPITI AND MOOSE submitted by NORMAND LUCIEN COOL in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in WILDLIFE PRODUCTIVITY AND MANAGEMENT.

[redacted]

DATED: March 12, 1992

## DEDICATION

To my wife Rejeanne and to my children Julianne and Patrick

## ABSTRACT

Digestion trials were conducted with 8 wapiti (*Cervus elaphus*) and 8 moose (*Alces alces*) calves during their first winter to validate and calibrate fecal crude protein (FCP) and urinary creatinine, urea, urea:creatinine ratio (U/C), cortisol and cortisol:creatinine ratio (C/C) as indicators of nutritional and physiological status.

Metabolizable energy (ME) required for maintenance and gain was calculated by regressing ME intake against liveweight change. Maintenance requirements of wapiti were estimated to be 547 $kJ/W^{0.75}.d$ compared with 600 $kJ/W^{0.75}.d$ for moose. Corresponding values for liveweight gain were 28 and 27 kJ/g, respectively. Differences between species were not significant.

Fecal crude protein concentrations were positively related to nitrogen intake in both wapiti (P=0.002) and moose (P=0.005). However, reducing the low protein (LP, 8.1-9.6% crude protein) diet to 50% of a*d libitum* intake did not cause a corresponding drop in FCP. Fecal crude protein concentrations were less sensitive to changes in body condition.

Creatinine was a satisfactory denominator for urinary metabolite ratios. Its daily excretion was relatively constant at 0.8 $mmol/W^{0.75}.d$ and was not significantly affected by diet , ambient temperature nor daily urine volume.

Urinary urea excretion and urea:creatinine ratios (U/C) were positively related to nitrogen intake over a wide range of intakes. A rise associated with tissue catabolism was not detected in the pen trials.

Cortisol:creatinine ratios (C/C) were elevated in lean animals losing over 5 $g/W^{0.75}.d$. Cortisol excretion and C/C ratios declined to within normal range 14 days after LP moose were refed a high protein diet *ad libitum*. U/C ratios and FCP obtained from wild wapiti and moose reflected changes in nitrogen availability. Adult males had lower indices. Only 1 of 90 snow urine samples had measurable cortisol so this index is limited for monitoring progressive changes in body condition during winter.

Urinary U/C and FCP offer a reliable index of changes in nitrogen availability and diet quality during winter. Rising U/C ratios occurred in animals during lean-tissue catabolism. Although cortisol may be an insensitive indicator, its presence in snow urine is a definitive signal of stress.

## ACKNOWLEDGMENTS

I extend my thanks to the Canadian Parks Service for giving me the opportunity and the support to complete this research. I am especially thankful to Elk Island National Park chief park warden Jack Willman for giving me the freedom to carry out this research and for fostering a progressive work environment.

I am very grateful to my supervisor Dr. R.J. Hudson for his enthusiasm and encouragement. Without his guidance and support this research on wild ungulates could not have been done.

I am grateful to Dr R.J. Christopherson and Dr W.M. Samuel for their helpful editorial comments and to Dr Alex Hawley for reviewing the research proposal. I would also like to thank Dr J. Thompson for the information and discussions he provided on biochemical processes during the study.

I am thankful to Canadian Parks Service regional biologist Dave Poll, Elk Island National Park superintendent Fred Bamber and Animal Science Department chairman Dr M. Price for corresponding with the public on issues dealing with the study.

I would also like to thank park warden Peter Deering and research technician Chris Wilke for their field assistance and to Olive Dodd and Chuck Blyth for their technical assistance regarding report production. I am also grateful to the warden staff who helped complete the metabolism crates.

I thank Chris Olsen for providing logistical support at the Ministik Wildlife Research Station and to Sean Archibald, Zhigang Jiang and especially Ray Nixdorf for their assistance with calf rearing and facility management.

I am grateful to Animal Science Laboratory Supervisor Terry Fenton and to Anya Nowinska for their technical support and especially to technician Pat Marceau for her laboratory assistance.

I am thankful to statistician Ray Wiengardt for his advice and assistance in statistically analyzing the data.

I thank Gene Irwing and Dr R. Kinniburgh and the staff at Dr S. Hanson medical laboratories for their advice and laboratory assistance.

I would also like to thank The Alberta Fish and Wildlife Division for providing orphaned moose calves.

Finally, to my wife Rejeanne and to my children Julianne and Patrick, I thank them for their interest and support and for their confidence in me to complete this work.

## TABLE OF CONTENTS

ABSTRACT
ACKNOWLEDGMENTS
TABLE OF CONTENTS
LIST OF TABLES
LIST OF FIGURES
LIST OF APPENDICES
GLOSSARY OF ABBREVIATIONS

1.0 INTRODUCTION ..... 1
2.0 STUDY AREA ..... 4
3.0 METHODS AND MATERIALS ..... 4
3.1 CALF MANAGEMENT ..... 4
3.2 NUTRITIONAL TREATMENTS ..... 5
3.3 DIGESTION TRIALS ..... 6
3.4 FIELD SAMPLING ..... 7
3.5 CHEMICAL ANALYSIS ..... 7
3.6 STATISTICAL ANALYSIS ..... 8
4.0 RESULTS ..... 8
4.1 PERFORMANCE ..... 8
4.1.1 Live Weight Change ..... 8
4.1.2 Intake and Diet Digestibility ..... 9
4.1.3 Requirements for Maintenance and Gain ..... 9
4.2 NUTRITIONAL INDICES ..... 10
4.2.1 Fecal Crude Protein ..... 10
4.2.2 Urinary Creatinine ..... 10
4.2.3 Urinary Urea ..... 10
4.2.4 Urinary Cortisol ..... 11
5.0 FIELD APPLICATION ..... 11
6.0 DISCUSSION ..... 30
6.1 PERFORMANCE ..... 30
6.1.1 Growth and Digestion ..... 30
6.1.2 Requirements for Maintenance and Gain ..... 30
6.2 CALIBRATION ..... 31
6.2.1 Fecal Crude Protein ..... 31
6.2.2 Urinary Creatinine ..... 31
6.2.3 Urinary Urea and Cortisol ..... 32
6.3 FIELD APPLICATION ..... 34
7.0 MANAGEMENT IMPLICATIONS ..... 37
8.0 LITERATURE CITED ..... 39

APPENDICES ..... 43

## LIST OF TABLES

Table 1.Ingredients, fibre, crude protein and gross energy (% of dry matter) of high protein (HP) and low protein (LP) diets fed 8 penned wapiti and 8 penned moose calves. .....5

Table 2. Trial date, feeding level and feeding period for 8 penned wapiti and 8 penned moose calves during the digestion trials. .....6

## LIST OF FIGURES

Figure 1. Bi-monthly live weights of 8 penned wapiti and 8 penned moose calves from early December 1990 to late March 1991. The data (mean±SE) were significantly different (P=0.05) in early March for wapiti and from early February to late March for moose. ....13

Figure 2. Dry matter intake (DMI,g/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to February 1991. Low protein groups (LP) were restricted to 50% intake for the February trial. The LP moose were fed a high protein diet for the March trial. The data (mean±SE) are significantly different between groups (P=0.05) for January and February for wapiti and February for moose. No data were obtained for March. ....14

Figure 3. Digestible dry matter intake (DDMI, g/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to February 1991. Low protein groups (LP) were restricted to 50% intake for the February trial. The LP moose were fed a high protein diet (HP) for the March trial. The data (mean±SE) are significantly different between groups (P=0.05) from December to February for wapiti and February for moose. No data were obtained for March. .. ....15

Figure 4. Relationship between average daily gain (ADG), and metabolizable energy intake (ME) and digestible nitrogen intake (DNI) of 8 penned wapiti and 8 penned moose from December 1990 to March 1991 ....16

Figure 5. Fecal crude protein (FCP) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991. The low protein groups (LP) were restricted to 50% intake for the February trial. The LP moose were fed a high protein diet (HP) for the March trial. The data (mean±SE) are significantly different (P=0.05) between groups from January to March for wapiti and moose. ....17

Figure 6. Relationship between fecal crude protein (FCP) and digestible dry matter intake (DDMI), digestible nitrogen intake (DNI) and average daily gain (ADG) in 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991....18

Figure 7. Daily creatinine excretion (mmol/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991. The data (mean±SE) are significantly different (P=0.05) for January for wapiti and December to February for moose. .. ....19

Figure 8. Daily urea nitrogen (mmol/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991. The data (mean±SE) are significantly different (P=0.05) from December to March for wapiti and from January to February for moose....20

Figure 9. Urea:creatinine ratio (U/C) of 8 penned wapiti and 8 penned moose calves obtained from first urinations from December 1990 to March 1991. The data (mean±SE) are significantly different (P=0.05) between groups from January to early March for wapiti and moose. ....21

Figure 10. Relationship between digestible nitrogen intake (DNI) and urea:creatinine ratio (U/C), of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991. ....22

Figure 11. Daily cortisol excretion (nmol/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991. There were no significant differences (P=0.05) between groups for wapiti and moose. Missing data are denoted by blanks. The standard error is presented as a T over each bar. ....23

Figure 12. Cortisol:creatinine ratio (C/C) of 8 penned wapiti and 8 moose calves obtained from first urinations from December 1990 to March 1991. Missing data are denoted by blanks. The data (mean ± SE) are significantly different (P=0.05) between groups for early March for moose. ....24

Figure 13. Relationship between average daily gain (ADG) and Cortisol:creatinine ratio (C/C) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991.. ....25

Figure 14. Urea:creatinine ratio (U/C) of wild wapiti and moose from Elk Island National Park obtained from November to April of 1989/90. The data are presented as Student-Newman-Keuls Means and are significantly different between years (P=0.05) for November, December and March for moose. Missing data are denoted by blanks.. ....26

Figure 15. Fecal crude protein (FCP) of wild wapiti and moose from Elk Island National Park obtained from November to April of 1989/90 and 1990/91. The data are presented as Student-Newman-Kewls Means, and they are significantly different between years (P=0.05) for November and December for wapiti, and February for moose The missing data is denoted by blanks. The standard error is presented as a T over each bar....27

Figure 16. Age and gender differences in Urea:creatinine ratio (U/C) and fecal crude protein (FCP) in wild wapiti and moose from Elk Island National Park obtained from November to April of 1989/90 and 1990/91. The data are significantly different (P=0.05) between age and gender for adult male wapiti and adult male moose for U/C and FCP. ....28

Figure 17. Urea:creatinine (U/C) and Cortisol:creatinine ratios of adult wapiti stags from Elk Island National Park and from the Ministik Wildlife Research Station obtained from snow urine in February 1990. No cortisol was detected in the wapiti stags from the Ministik Wildlife research Station. The standard error is presented as a T over each bar ....29

## LIST OF APPENDICES

Appendix 1. Wapiti and moose calf information.....43

Appendix 2. Fat, protein and lactose content of milk formulas fed to wapiti and moose calves.....44

Appendix 3. Moose and wapiti calf feeding and weaning schedule.....45

Appendix 4. Percent relative forage density of rumen samples of wild wapiti, moose and white-tailed deer from Elk Island National Park.....46

Appendix 5. Carcass condition indices, urine and blood characteristics of moose, wapiti and white-tailed deer from Elk Island National Park.....47

Appendix 6. Urinary mineral, creatinine and urea excretion (millimoles/day) of penned wapiti and moose calves. .....48

Appendix 7. Crude protein, fibre, trace mineral and gross energy of common forages consumed by wild wapiti, moose and deer from Elk Island National Park. .....49

Appendix 8. Monthly urinary mineral ratios to creatinine obtained from urine deposited on snow by wild wapiti and moose from Elk Island National Park.....50

Appendix 9. Age and gender differences in urinary mineral ratios to creatinine obtained from urine deposited on snow by wild wapiti and moose from Elk Island National Park.....51

## GLOSSARY OF ABBREVIATIONS

| | |
|---|---|
| ADG | Average daily gain |
| CP | Crude protein |
| C/C | Cortisol:creatinine ratio |
| .d | Day |
| DDMI | Digestible dry matter intake |
| DMI | Dry matter intake |
| DNI | Digestible nitrogen intake |
| FCP | Fecal crude protein |
| HP | High protein |
| kJ | kilojoules |
| LP | Low protein |
| ME | Metabolizable energy intake |
| MEM | Metabolizable energy for maintenance |
| $W^{0.75}$ | Metabolic weight |
| mmole/l | millimole/litre |
| nmole/l | nanomole/litre |
| P | Probability |
| SE | Standard error |
| U/C | Urea:creatinine ratio |

## 1.0 INTRODUCTION

Monitoring the nutritional and physiological condition of wild ruminants during winter allows managers to identify ecological constraints and implement mitigative measures. Monitoring becomes more important in protected areas where large predators are absent and barriers limit dispersal.

Elk Island National Park located in central Alberta is such an insular ecosystem. It lacks predators larger than coyotes *(Canis latrans)* and is enclosed by a 2.2 m high game fence. The park harbours very high ungulate numbers. The annual surplus of wapiti, moose and wood bison *(Bison bison athabascae)* are live-trapped to restock depleted areas in Canada. Plains bison *(Bison bison)* are sold to private interests by live tender.

Annual aerial and range surveys monitor ungulate and vegetation dynamics. Although concerted effort has been made to establish long term trends, population and vegetation surveys cannot assess the annual or seasonal balance of herbivores and their food supply. Park managers have the responsibility to adopt more sensitive and direct approaches to monitoring plant-herbivore equilibria.

Wild ruminants are well-adapted for winter survival and their ability to metabolise fat (Verme and Ozoga 1980, Abbott et al. 1984) and protein (Klasig 1985) is well documented. In winter, low metabolic rate and voluntary intake decrease the requirement for protein and energy (Schwartz et al. 1988, Renecker and Hudson 1990). However, when maintenance requirements are not met and body condition declines, dry matter intake usually increases to compensate (Schwartz et al. 1988). If nutritional demands are still not satisfied, alternative sources of energy and amino acids are required.

Fat and protein catabolism are normal metabolic processes for wild ruminants living in harsh winter environments (Dalton 1967, Wallmo et al. 1977, Baker and Hobbs 1985, Delgiudice et al. 1991). Nitrogen can be spared through urea recycling (Mould and Robbins, 1981) by both domestic (Topps and Elliot 1964, Thorton and Wilson 1972) and wild ruminants (Swift 1983).

During severe winters, fat depots are depleted, marrow fat is mobilised (Mitchell et al. 1976), and muscle catabolism increases (Torbit et al. 1985). Monitoring metabolites that

reflect progressive changes in body condition offers an index of nutritional and physiological status.

Indices of metabolic status have been studied extensively (Riney 1955, Franzman and LeResche 1978, Mould and Robbins 1981, Waid and Warren 1984) and numerous studies have focused on the causes of starvation in wild ruminants (Owen et al. 1969, deCalesta et al. 1974, Hobbs 1989). Fecal crude protein (FCP) is one measure of forage quality, nitrogen status and growth (Gates and Hudson 1981, Lesley and Starkey 1985). Strong relationships were reported between FCP and rate of gain in wapiti (Gates and Hudson 1981). However, phenolic compounds in many dicotyledonous forages interfere with nitrogen digestion and may limit FCP as an indicator of nitrogen status (Mould and Robbins 1981).

Metabolites recovered from urine deposited in snow (snow urine) and from bladder urine show promise (Waid and Warren 1984, Delgiudice et al. 1989). These are usually expressed as ratios to creatinine to account for dilution. Urea:creatinine (U/C) ratios have been used as indicators of accelerated protein catabolism (Saltz and White 1991a,b, Delgiudice et al. 1991). However, protein and energy intake, tissue catabolism, and urea recycling cannot be distinguished by U/C ratios alone (Warren et al. 1982) and additional indices are required for this distinction (Seal et al. 1978).

Cortisol, a hormone secreted by the adrenal cortex, is linked to increased metabolic activity (Beisel et al. 1964, Chao and Brown 1984) and calorigenesis in cattle (Yousef and Johnson 1967). Cortisol:creatinine ratios (C/C) from bladder urine of deer are related to population density and are reliable measures of energy deficit (Saltz and White 1991a). Together, U/C and C/C ratios distinguish high levels of urea nitrogen caused by high dietary crude protein from those caused by muscle catabolism.

These techniques are attractive as management tools, particularly in national parks, because they do not require capture and restraint of animals. However, several important factors require validation. Urine creatinine is a reliable index of lean muscle mass (Vestergaard and Leverett 1958, Coles 1980). Therefore, it may serve as a useful denominator in ratios with other metabolites (Saltz and White 1991a). However, the relationship of creatinine excretion to muscle mass has not been validated in wapiti and moose. The recovery of cortisol in snow urine also remains to be studied because initial investigations are inconclusive (Saltz and White 1991a).

The objective of this study was to calibrate urinary and fecal indices for wapiti and moose and to apply the technique in Elk Island National Park. This involved:

1. Validating the use of creatinine as a denominator with other metabolites,
2. Determining the effect of dietary energy and protein and animal performance on fecal crude protein, urinary urea and urinary cortisol.
3. Applying these metabolic indices to evaluate the nutritional and physiological status of wapiti and moose at Elk Island National Park.

To this end, trials using high and low crude protein diets were conducted using hand-reared wapiti and moose calves. Total collection trials were considered because absolute urea nitrogen or creatinine excretion cannot be estimated and random urine and snow urine present uncontrollable sources of variation (Warren et al. 1981, Sauberlich et al. 1973). Calibrated fecal and urinary indices were then applied to snow urine and feces collected from captive and wild wapiti and moose.

Several specific hypotheses guided this study:

1. Nutritional indices will differ between wapiti and moose because of differences in digestion and recycling efficiency, diet selection and robustness. This will affect their nitrogen and energy requirements for maintenance.
2. FCP will reflect diet quality and intake rather than body condition.
3. Urinary urea nitrogen excretion and U/C ratios will be elevated by high dietary intake or conversely very low intakes with concomitant tissue catabolism.
4. Because of its gluconeogenic effect, urinary cortisol will distinguish high levels of urea nitrogen caused by the availability of crude protein from those caused by muscle catabolism.

## 2.0 STUDY AREA

Wapiti and moose calves were reared, and feeding trials were conducted at the University of Alberta's Ministik Wildlife Research Station. Field sampling was conducted in the Wood Bison Area of Elk Island National Park, 40 km east of Edmonton. The Wood Bison Area encompasses 4300 ha enclosed by a 2.2 m high game fence which limits the movement of most large ungulates. The area harbours high live biomass densities of wood bison (30 kg/ha), wapiti (20 kg/ha), moose (11 kg/ha) and white-tailed deer *(Odocoileus virginianus),* (6 kg/ha). Both study areas are situated in the Beaver Hills, a stagnant end moraine typified by knob and kettle topography.

The vegetation is classified as Parkland Boreal Forest Transition (Zoltai 1975). Uplands are dominated by trembling aspen *(Populus tremuloides)* and balsam popular *(Populus balsamifera)* interspersed with grasslands dominated by bluegrass *(Poa* spp.*).* Wetlands are comprised mainly of willow (*Salix* spp.), sedges (*Carex* spp.) and sphagnum bogs with pockets of black spruce*(Picea mariana).*

Temperature extremes range from -50 to 30 C (Olson 1985). About 500 mm of precipitation falls with 25% as snow. Snow accumulation usually begins in mid November and persists until April.

## 3.0 METHODS AND MATERIALS

### 3.1 CALF MANAGEMENT

Eight moose calves (4 males, 4 females) were obtained from the wild at 3 to 25 days of age (Appendix 1). Eight wapiti calves (4 males, 4 females) were obtained at ages of 2 to 60 days from resident hinds at the Ministik Wildlife Research Station. The calves were held in 25 X 70 m outdoor pens with small 2 X 2 X 1.5 m plywood shelters.

A 1:1 mixture of bovine whole milk and lamb milk replacer (on a 20% dry matter basis) was fed to calves from the date of acquisition to September (Appendix 2 and 3). Calves had free access to water, mineral blocks and alfalfa-barley pellets (17% crude protein). About 100 kg of fresh cut aspen and willow browse was provided once per week

throughout the summer and fall. Calves were weighed twice a week until weaned and once a week thereafter.

### 3.2 NUTRITIONAL TREATMENTS

Two diets were designed to approximate the quality of natural summer and winter diets of wild ruminants in the Cooking Lake region (Table 1). To evaluate the interacting effects of current dietary intake and body condition, 2 male and 2 female calves of each species were fed a diet varying in 16.6% to 20.3% crude protein content (HP diet) *ad libitum* during winter.

Table 1. Ingredients, fibre, crude protein and gross energy (% of dry matter) of high protein (HP) and low protein (LP) diets fed to penned wapiti and moose calves.

| Month | DEC | JAN | | FEB | | MAR | |
|---|---|---|---|---|---|---|---|
| Group | HP/LP | HP | LP | HP | LP | HP | LP |
| Meal | 21.2 | 21.2 | - | 21.3 | - | 21.3 | - |
| Barley | 24.6 | 24.6 | 14.2 | 24.7 | - | 24.7 | - |
| Beet pulp | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| Oat hulls | - | - | 29.5 | 20.0 | 65.0 | 20.0 | 65.0 |
| Aspen | 0.0 | 20.0 | 20.0 | - | - | - | - |
| Perma pel | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Mineral mix | 3.2 | 3.2 | 5.3 | 3.0 | 4.0 | 3.0 | 4.0 |
| Crude protein | 16.6 | 20.3 | 9.6 | 18.6 | 8.1 | 19.0 | 8.1 |
| NDF % | 29.5 | 29.5 | 44.0 | 32.0 | 56.5 | 32.0 | 56.5 |
| ADF % | 17.5 | 16.8 | 24.0 | 16.1 | 28.2 | 16.1 | 28.2 |
| Lignin % | 1.7 | 2.6 | 3.5 | 2.7 | 4.5 | 2.7 | 4.5 |
| Gross energy (kJ/g) | 17.1 | 17.1 | 17.9 | 16.8 | 16.7 | 16.8 | 16.7 |

- = ingredient not included in diet
NDF = Neutral detergent fiber
ADF = acid detergent fiber

Table 2. Trial date, feeding level and feeding period of penned wapiti and moose calves during the digestion trials.

| Treatment group | HP/LP | HP | LP | HP | LP | HP | LP |
|---|---|---|---|---|---|---|---|
| Feeding level | A/L | A/L | A/L | A/L | 1/2 A/L | A/L | A/L |
| Feeding period | Nov 1 - Dec 6 | Dec 7 - Jan 21 | | Jan 22 - Mar 3 | | Mar 4 - Mar 24 | |
| Pen trials | Nov 29 - Dec 6 | Jan 14 - Jan 21 | | Feb 17 - Feb 24 | | Mar 17 - Mar 24 | |

HP = wapiti and moose calves fed high protein diets
LP = wapiti and moose calves fed low protein diets
A/L = *ad libitum* intake
1/2 = 50% of *ad libitum* intake

Corresponding groups were fed diets varying in 8.1% to 9.6% crude protein (LP diet) for the same period. Intake was restricted to 50% *ad libitum* from mid January to early March for LP groups. LP moose were returned to the HP diet *ad libitum* in early March, 3 weeks before the last trial. The LP wapiti remained on the LP diet in March but their feed allowances were increased to *ad libitum*. The LP groups were also fasted for twenty four hours during the first collection in February to explore the effects of acute feed restriction such as would occur after heavy snowfalls.

### 3.3 DIGESTION TRIALS

Digestion trials were conducted each month from December to March following a three week dietary adjustment. Each trial consisted of a two day 24-hour collection of feces and urine. First urinations were also collected. To reduce stress, collection days for each group alternated so animals never spent more than 24 hours in a metabolism crate. Ambient temperatures were recorded daily at Ministik.

A metabolism crate consisted of a 2 X 1.5 X 2 m high plywood box with a large rear entrance and a small front window used for feed and water and to monitor behaviour. The floor was a metal grate coated with vinyl which allowed urine to flow onto a collecting tray comprised of a wooden frame with greenhouse polyvinyl sheathing. Cheese cloth was stretched and stapled on the tray to prevent fecal contamination. This was discontinued in cold weather because the urine froze and pooled on the cheese cloth. The most reliable method for preventing fecal contamination during cold weather was to remove the feces and wipe the tray. Crates, collections trays and containers were washed daily.

## 3.4 FIELD SAMPLING

From December 1 to March 31 (winter) of 1989/90 and 1990/91, 123 snow urine and 89 fecal samples from wapiti and 92 snow urine and 85 fecal samples from moose were collected in Elk Island National Park. Fifteen samples were obtained from newly captured wapiti stags at Elk Island National Park and 12 samples from resident wapiti stags at the Ministik Research Station. Samples were collected from animals observed urinating and defecating to distinguish age and gender. Samples were frozen at -20 C until analysis.

## 3.5 CHEMICAL ANALYSIS

Rations and feces were analyzed for crude protein concentration (nitrogen X 6.25) by the macro Kjeldahl procedure (A.O.A.C., 1965). Fecal crude protein concentration (FCP) is expressed in grams of crude protein per 100 grams of feces on a dry matter basis. Lignin, neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Goering and Van Soest (1970). Gross energy was determined by bomb calorimetry.

Acid insoluble ash (AIA) was used as an internal marker (Van Keulen and Young 1977) to estimate digestibility. The apparent digestibility (AD) was expressed as the percent of dry matter digested. Digestible dry matter intake (DDMI) and digestible nitrogen intake (DNI) were expressed in $g/W^{0.75}.d$. Digestible dry matter intake and DNI were not calculated for the March trial because fecal weights were not obtained.

Metabolizable energy requirements for maintenance (MEM, $kJ/W^{0.75}.d$) and live weight gain (kJ/g) were obtained from the y intercept and slope of regressions of metabolizable energy (GE x 0.82 x DDMI) against average daily gain (ADG, $g/ W^{0.75}.d$). The constant of 0.82 is a conversion factor of digestible energy to metabolizable energy estimated for sheep and cattle (Blaxter et al. 1966). The y intercept and slope of DNI against ADG was also calculated.

Apparent digestible energy was considered to be a one-to-one relationship with apparent digestibility of dry matter (Robbins et al. 1975). Digestible nitrogen intake calculated from total fecal collections and from AIA ratios were strongly correlated ( $Y = 0.93x + 0.05, r^2 = 0.99$).

Twenty four hour urine collections were measured in a graduated beaker. Frozen urine was thawed and mixed thoroughly with a teflon rod and aliquots were decanted into

sterile urine specimen containers. Samples were chilled in ice and usually analyzed the day of collection. When immediate analysis was not possible, the samples were frozen at -20 C. Samples of urine were also taken during the trials and analyzed accordingly. Grab samples from one hour collections were also taken in early March. A clinical laboratory (Dr. S. Hanson & Associates Medical Laboratory, Edmonton, Alberta) conducted the following analyses. Quantitative recovery of urea (diacetyl monoxime procedure),and creatinine (modified Jaffe procedure ) were measured by colorimetric determination. Cortisol from 24 hour collections and from snow urine was recovered by radioimmunoassay using the Kallestad Quanticoat technique. These data were presented as Urea to creatinine ratios (mmol/l):(mmol/l) (U/C) and cortisol to creatinine ratios (nmol/l):(mmol/l) (C/C). Creatinine is used because its excretion rate is usually proportional to muscle mass and is excreted at a constant rate in domestic ruminants (Coles 1980).

## 3.6 STATISTICAL ANALYSIS

A split-plot nested design was selected and calculated using the general linear model procedure (SAS, Carey NC). Analysis of covariance was used to interpret treatment effects. Simple linear regression analysis calculated energy requirements for maintenance and gain. Multiple comparison of means (Student-Newman-Keuls analysis) was employed to determine differences in mean monthly FCP and U/C ratios obtained from field collections. A Student's *t* test was used to compare HP and LP groups in specific trials.

# 4.0 RESULTS

## 4.1 PERFORMANCE

### 4.1.1 Live Weight Change

Live weight data is presented bi-monthly to emphasize the critical periods of weight loss (Figure 1). Differences in live weight from December 1990 to March 1991 were significant in HP and LP groups for wapiti (P=0.0005) and moose (P= 0.002). Moose were larger and continued to grow throughout the winter. The LP groups gained weight until the end of January when intakes were restricted. The LP moose lost weight by the end of February and began gaining weight in March when returned to the high quality diet. The HP moose continued gaining weight until late February although weight gains declined as winter progressed. HP wapiti followed a similar pattern but lost weight in late February. LP groups fed 50% of *ad libitum* intake lost 5-10% of their body weight

between late January and early March. No subcutaneous backfat could be palpated on LP moose and the two females of the group appeared thinner and in generally poorer condition than their HP counterparts. No visible difference was noticed in HP and LP wapiti despite their maintenance on the low quality diet into late March.

### 4.1.2 Intake And Diet Digestibility

Dry matter intake (DMI, g/$W^{0.75}$.d) of HP animals gradually increased from December to January and decreased to their lowest level in February (Figure 2). LP groups decreased intake slightly from December to January as they switched to the lower quality diet. The further reduction among LP animals in February was the result of reducing their feed allowance to 50% *ad libitum* intake.

The apparent digestibility of the high protein diet was 78% (SE=5.0) for wapiti and 72% (SE=5.0) for moose when they shared the same diet in December. Digestibility in HP groups remained relatively stable (72%, SE=4.0) during the winter. Apparent digestibility in LP wapiti decreased to 46% (SE=5.0) in February when the feed intake and quality were decreased. Digestibility in LP moose followed a similar pattern, reaching a low of 34% (SE=6.0) in February. Samples for estimation of digestibility were not collected in March.

Digestible dry matter intake (DDMI) is the product of dry matter intake and dry matter digestibility. For HP groups, DDMI was higher than LP groups in January and February (Figure 3). The slight increase in dietary protein in January elevated DDMI for HP groups. For LP groups, DDMI declined from mid December to late February as diet quality declined and feed allowances were restricted to 50% *ad libitum*.

### 4.1.3 Requirements For Maintenance And Gain

Metabolizable energy requirements for maintenance (intercept of ME against ADG) and gain (slope of ME against ADG) were not significantly different between wapiti and moose (Figure 4). Metabolizable energy requirements for maintenance were 547 (SE=75) kJ/$W^{0.75}$.d for wapiti and 600 (SE=86) kJ/$W^{0.75}$.d) for moose. Values for liveweight gain were 28 (SE=9) kJ/g for wapiti and 27 (SE=7) kJ/g for moose. Pooled regressions of DNI on ADG for both species gave an intercept of 0.95 g N/$W^{0.75}$.d (SE=0.12) and slope of 0.06 g N/g (SE=0.01).

## 4.2 NUTRITIONAL INDICES

### 4.2.1 Fecal Crude Protein

Fecal crude protein concentrations were influenced by dietary crude protein contents (CP) in both wapiti ($P = 0.002$) and moose ($P = 0.005$) (Figure 5). Generally, FCP was close to values of dietary CP. Pooled regressions of FCP against DDMI, DNI and ADG were weak and showed no major differences between species (Figure 6). Restricting intake in February had no significant effect on either species. FCP of LP moose rose sharply in March when they were returned to a high quality diet but the corresponding group of wapiti showed no change because they were maintained on the LP diet in March. The FCP of wapiti declined at cold temperatures ($P = 0.03$).

### 4.2.2 Urinary Creatinine

Creatinine excretion ranged narrowly from 0.8-1.0 mmol/$W^{0.75}$.d (Figure 7). Creatinine excretion in wapiti was relatively constant and wapiti maintained better body condition than moose. However, one female wapiti had a very high creatinine excretion in January. which elevated the pooled rate for the group. Creatinine excretion diminished in animals losing excessive weight as was the case in LP moose. HP moose also reduced creatinine excretion in February and this elevated U/C ratios for the group. Creatinine excretion did vary with gender. Female wapiti ($P=0.06$) and male moose ($P=0.03$) excreted more creatinine than the opposite gender. Creatinine excretion did not respond to diet quality, dry matter intake nor ambient temperature. Nor was its excretion rate significantly affected by changes in daily urine volume. Creatinine excretion increased in LP moose during the March trial 14 days after being refed the HP diet *ad libitum*.

### 4.2.3 Urinary Urea

Urea nitrogen excretion was higher on the high quality diet in both wapiti ($P = 0.006$) and moose ($P = 0.0001$) (Figure 8). Urea excretion decreased from January to February in HP groups due to a decreased DMI and reduction of dietary protein. Restricted intake and the 24-hour fast in February did not reduce excretion rates. The LP moose increased urea excretion in response to improved nutrition in March.

The U/C ratios showed basically the same pattern except for the U/C ratios of LP moose that surpassed all other groups in early March (Figure 9). U/C ratios were also elevated in HP moose in February because of diminished creatinine excretion rates. Pooled regression of U/C against DNI suggested slightly higher U/C ratios in moose although

this was not significant (Figure 10). Ambient temperature, dry matter intake and digestible dry matter intake had no effect on urea excretion in January and February.

### 4.2.4 Urinary Cortisol

Urinary cortisol was excreted between 3 to 4 nmol/$W^{0.75}$.d and was not significantly affected by diet quality until significant weight loss occurred (Figure 11). No 24-hour collection was made in early March when the highest weight losses occurred. However, C/C ratios were elevated from samples taken at the time (Figure 12). In early March, C/C ratios were markedly higher (P =0.0001) in LP moose.

LP animals losing more than 5 g/$W^{0.75}$.d had elevated C/C ratios (Figure 13). One female moose (Lucy) that lost 15 % of her body weight had the highest C/C (106.0) and U/C ratio (87.3). One moose from the HP group (Misty) that developed a chronic upper respiratory infection had the highest C/C ratio (3.03) of the group although the U/C ratio remained relatively constant.

Cortisol and urea excretion did not change as dramatically in wapiti, which appeared in much better condition than moose during the winter. However, some differences were observed. Wapiti males from the HP group (generally poorer condition than their counterparts) had higher C/C ratios (P = 0.001) than other wapiti. Diet, ambient temperature, DDMI, and DNI influenced neither cortisol excretion nor C/C ratios until weight loss occurred.

## 5.0 FIELD APPLICATION

Ratios of U/C in snow urine from wapiti and moose in Elk Island followed similar patterns as the LP moose, declining to their lowest values in February and rising in March and April. The U/C ratios were generally lower in 1990/91 than in the previous winter (Figure 14). U/C ratios were much lower in moose than wapiti. In wapiti, ratios fell from November to February and rose sharply in the spring. In moose, the most striking feature was the high mean ratio in samples from November 1990 due to one cow moose with a ratio of 26.

Fecal crude protein responded in a similar manner . The FCP in wapiti decreased throughout the winter with a rise in March and April (Figures 15). In contrast, FCP of moose were much lower and changed little from November to April.

Age and gender differences in over-winter urinary and fecal indices also were detected (Figure 16). The U/C ratios in adult male wapiti and adult bull moose were significantly lower (P=0.05) than other sex/age groups. FCP was lowest in adult males of both species.

Cortisol was detected in only one snow urine sample obtained from a wild bull moose in 1990/91. No cortisol was recovered from 90 other samples from wild wapiti and moose in 1990/91.

Cortisol, urea, and creatinine were recovered from snow urine from corralled wild adult wapiti stags in Elk Island National Park and penned tame stags at the Ministik Wildlife Research Station. U/C and C/C ratios were higher in wapiti from Elk Island than those from Ministik (Figure 17).

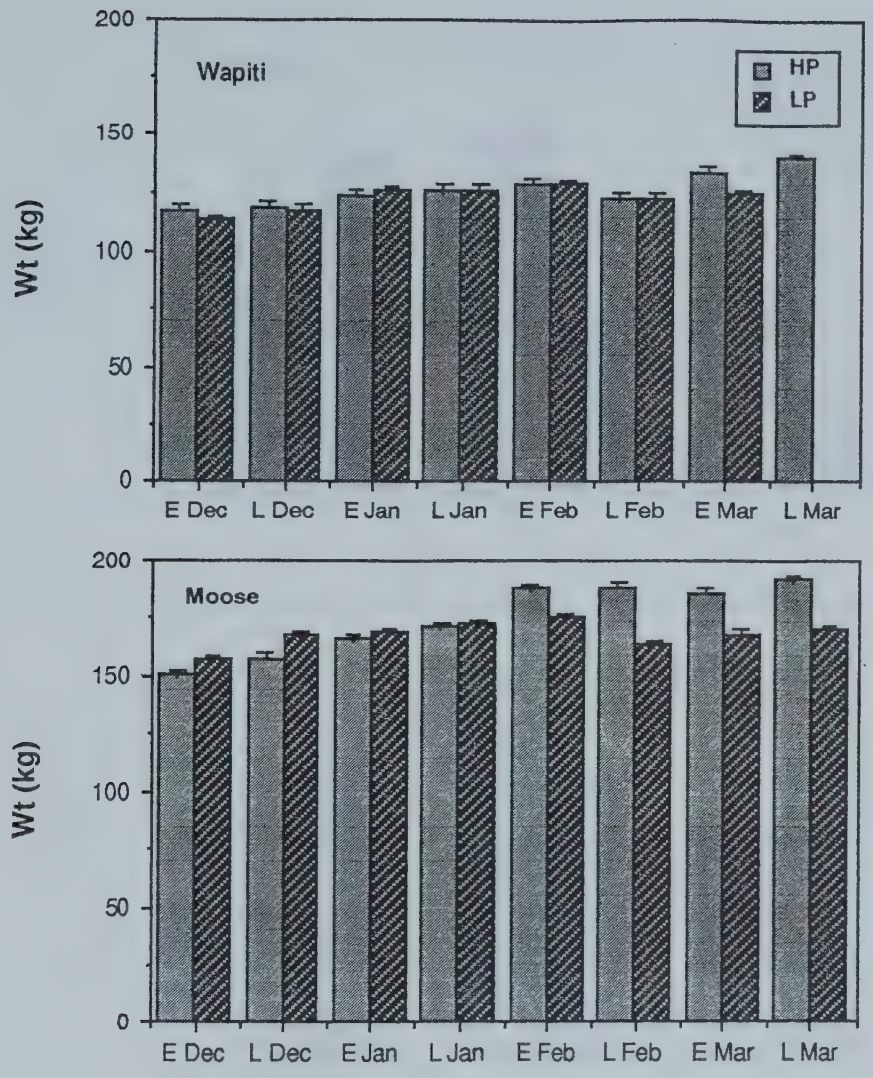


Figure 1. Bi-monthly live weights of 8 penned wapiti and 8 penned moose calves from early December 1990 to late March 1991. The data (mean±SE) were significantly different (P=0.05) in early March for wapiti and from early February to late March for moose.

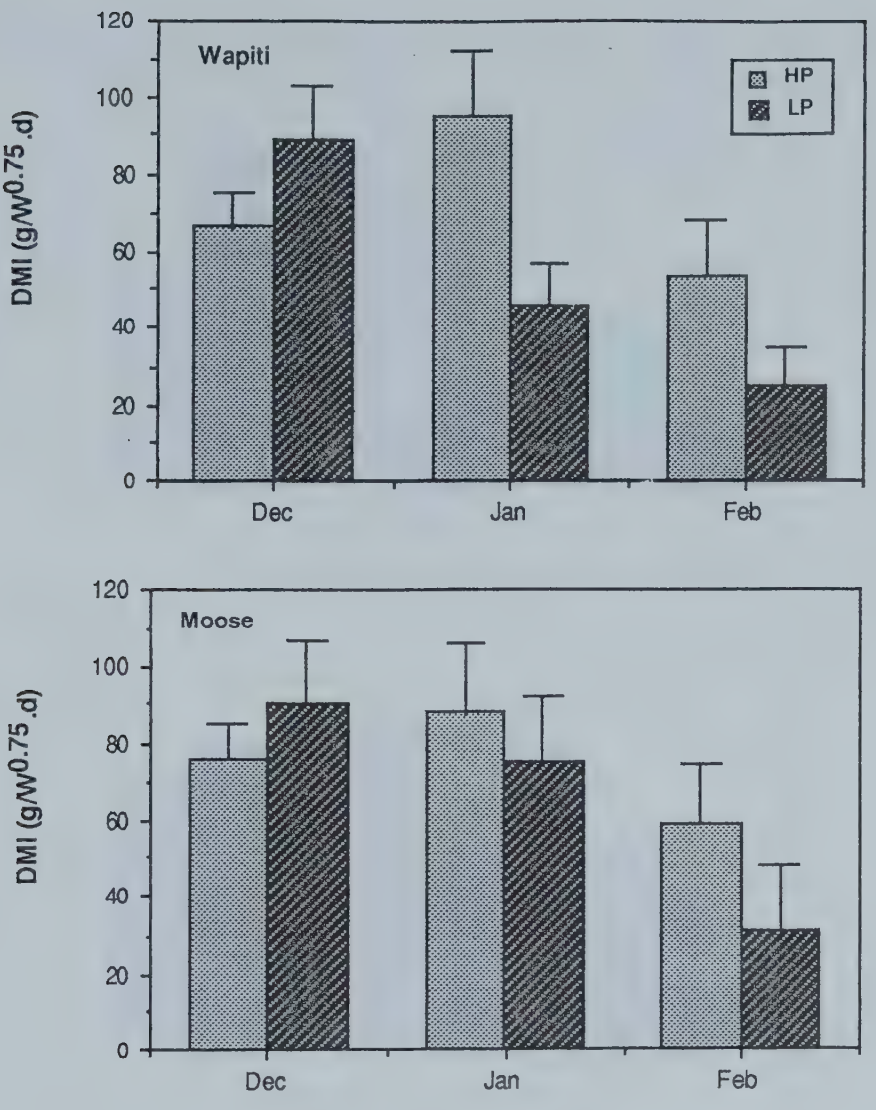


Figure 2. Dry matter intake (DMI,g/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to February 1991. Low protein groups (LP) were restricted to 50% intake for the February trial. The LP moose were fed a high protein diet for the March trial. The data (mean±SE) are significantly different between groups (P=0.05) for January and February for wapiti and February for moose. No data were obtained for March.

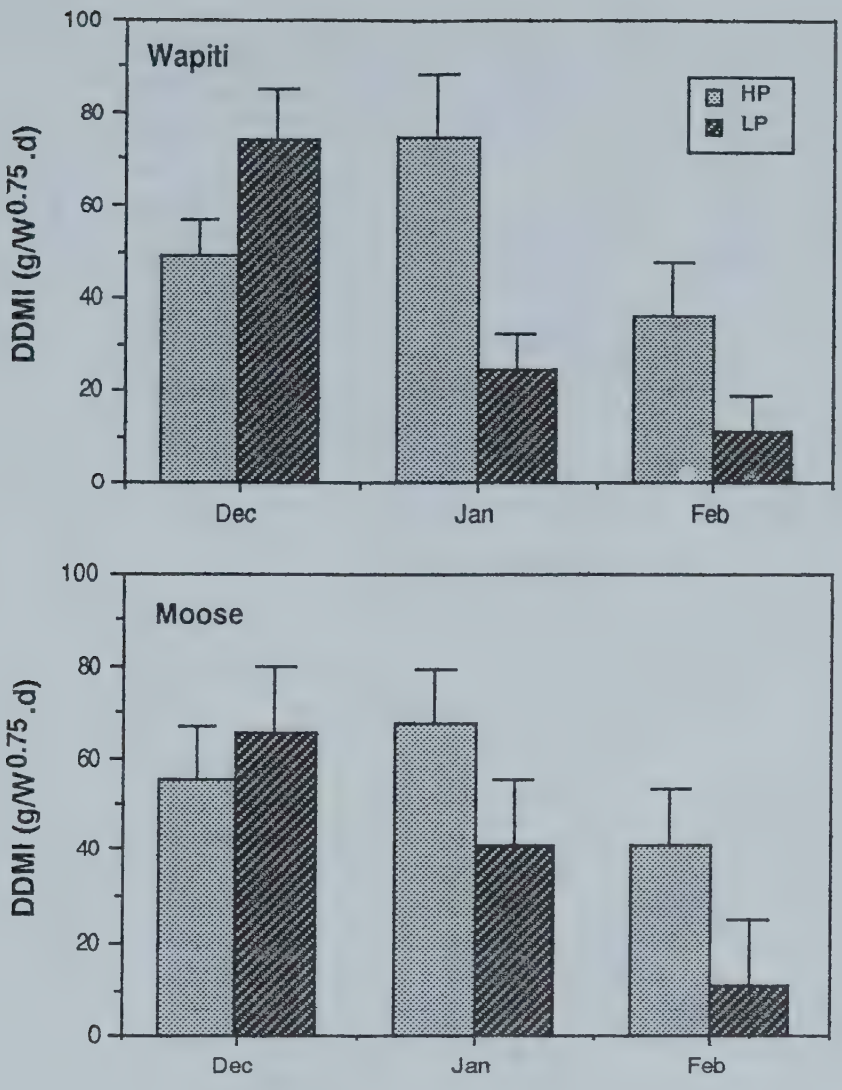


Figure 3. Digestible dry matter intake (DDMI, g/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to February 1991. The data (mean±se) are significantly different between groups (P=0.05) from December to February for wapiti and February for moose. No data were obtained for March.

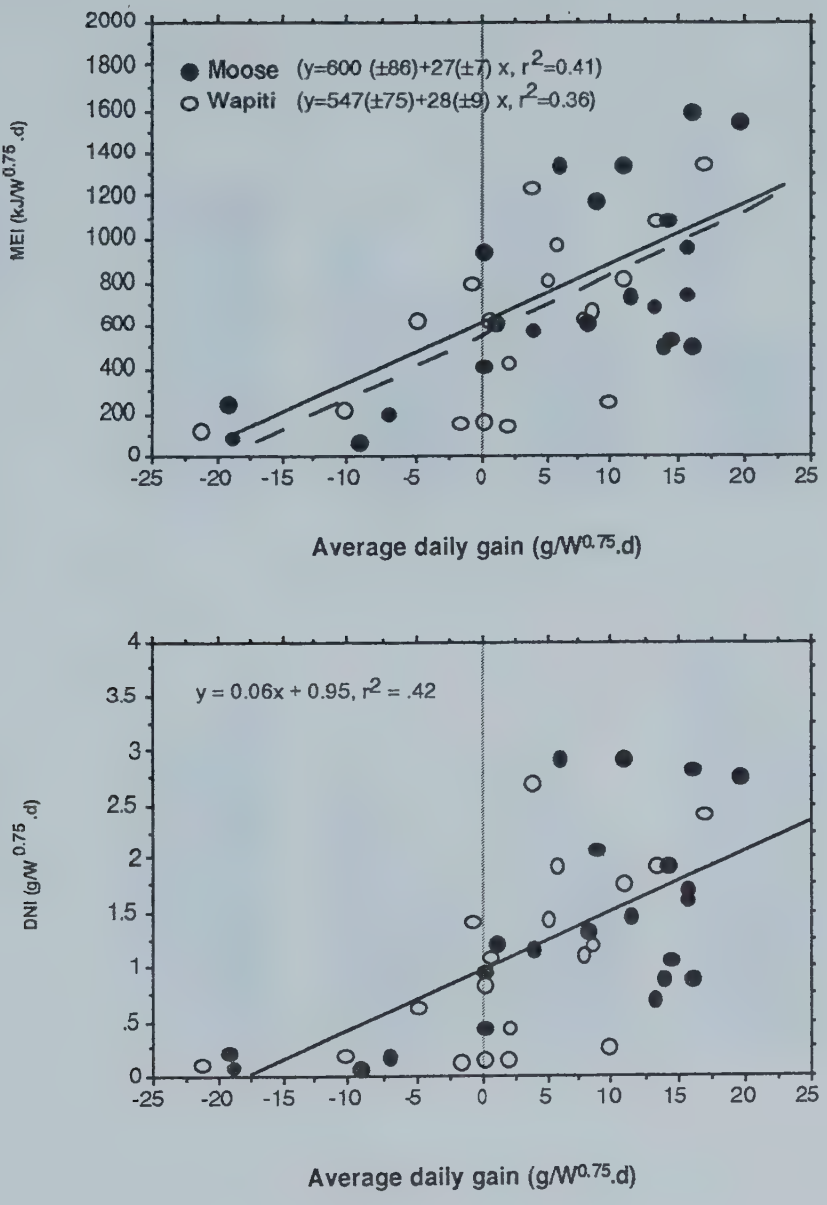
Moose (y=600 (±86)+27(±7) x, r2=0.41)
Wapiti (y=547(±75)+28(±9) x, r2=0.36)
MEI (kJ/W0.75.d)
Average daily gain (g/W0.75.d)
y = 0.06x + 0.95, r2 = .42
DNI (g/W0.75.d)
Average daily gain (g/W0.75.d)

Figure 4. Relationship between average daily gain (ADG), and metabolizable energy intake (MEI) and digestible nitrogen intake (DNI) of 8 penned wapiti and 8 penned moose from December 1990 to March 1991.

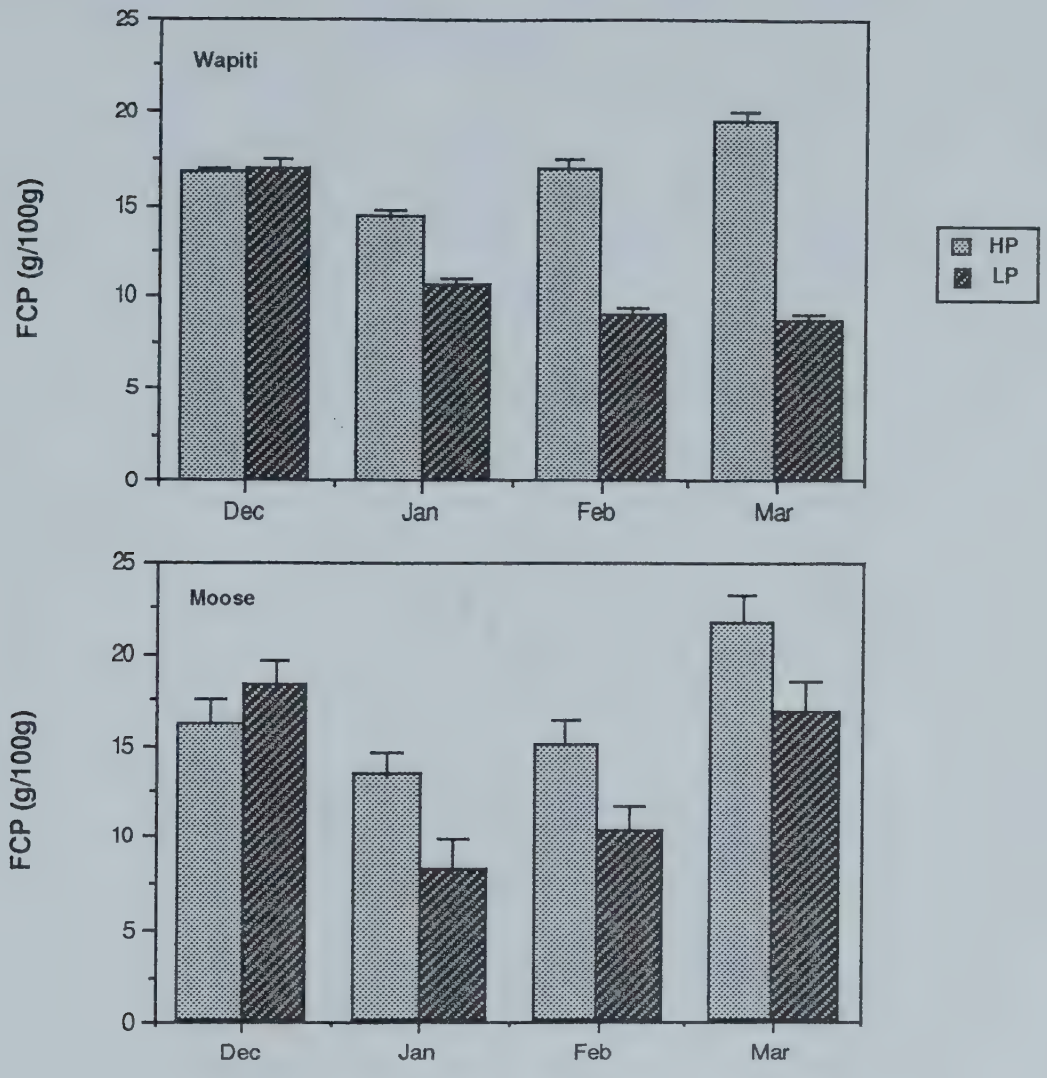


Figure 5. Fecal crude protein (FCP) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991. The low protein groups (LP) were restricted to 50% intake for the February trial. The LP moose were fed a high protein diet (HP) for the March trial. The data (mean±SE) are significantly different (P=0.05) between groups from January to March for wapiti and moose.

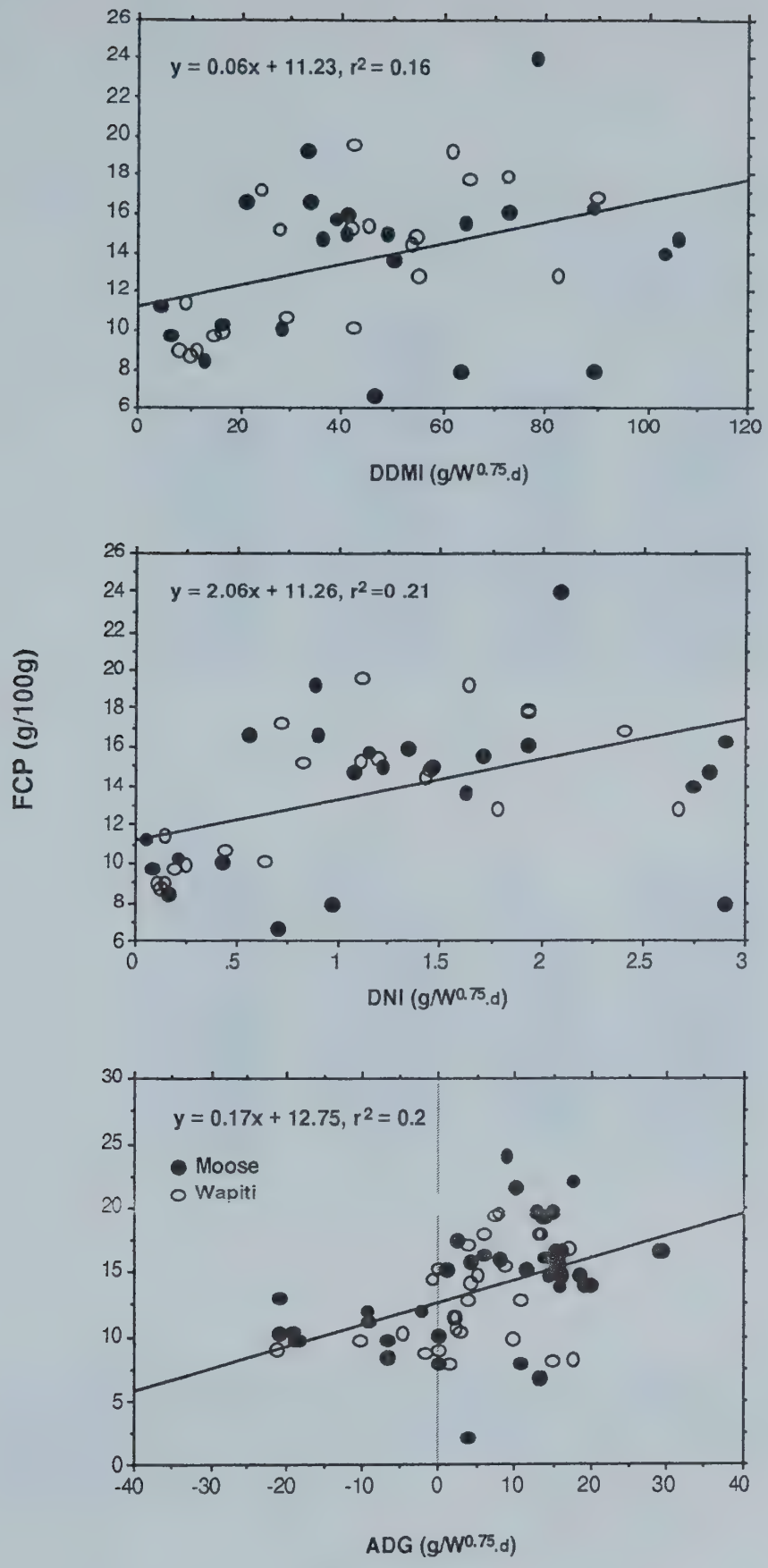


Figure 6. Relationship between fecal crude protein (FCP) and digestible dry matter intake (DDMI), digestible nitrogen intake (DNI) and average daily gain (ADG) in 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991

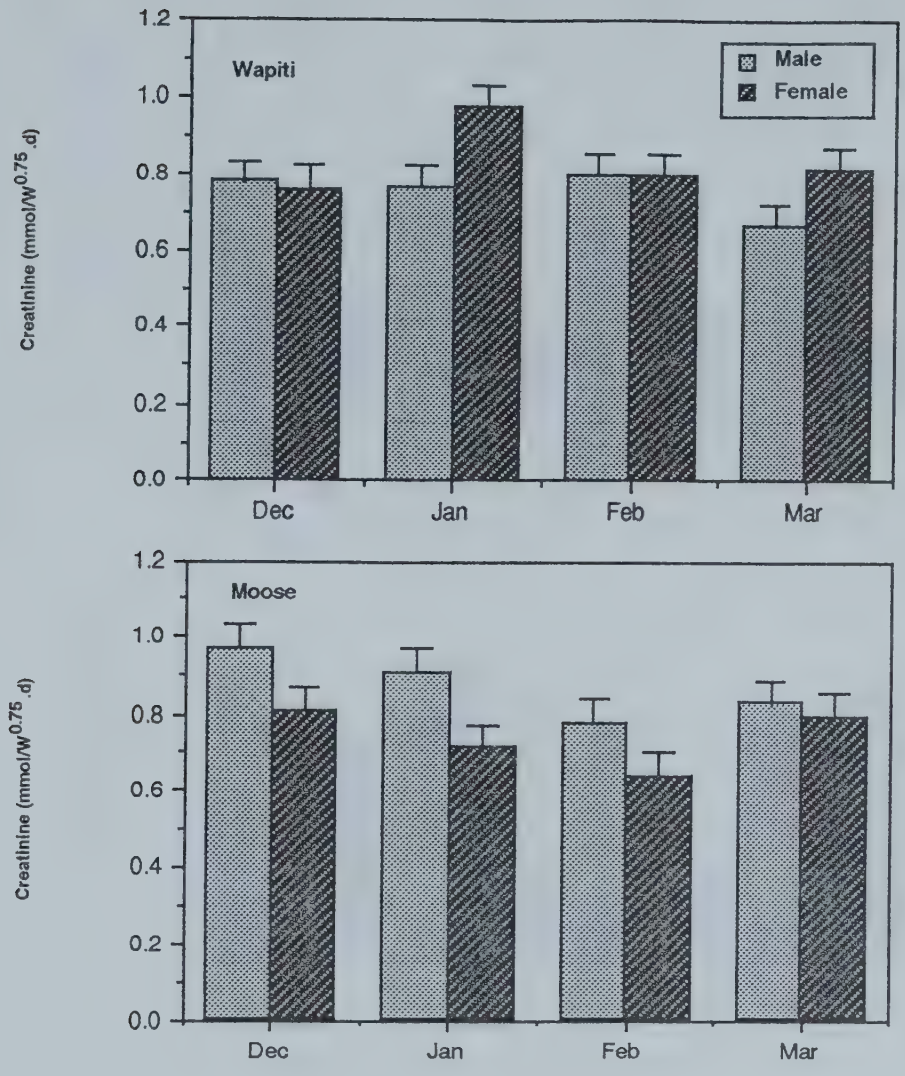


Figure 7. Daily creatinine excretion (mmol/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991. The data (mean±SE) are significantly different (P=0.05) for January for wapiti and December to February for moose.

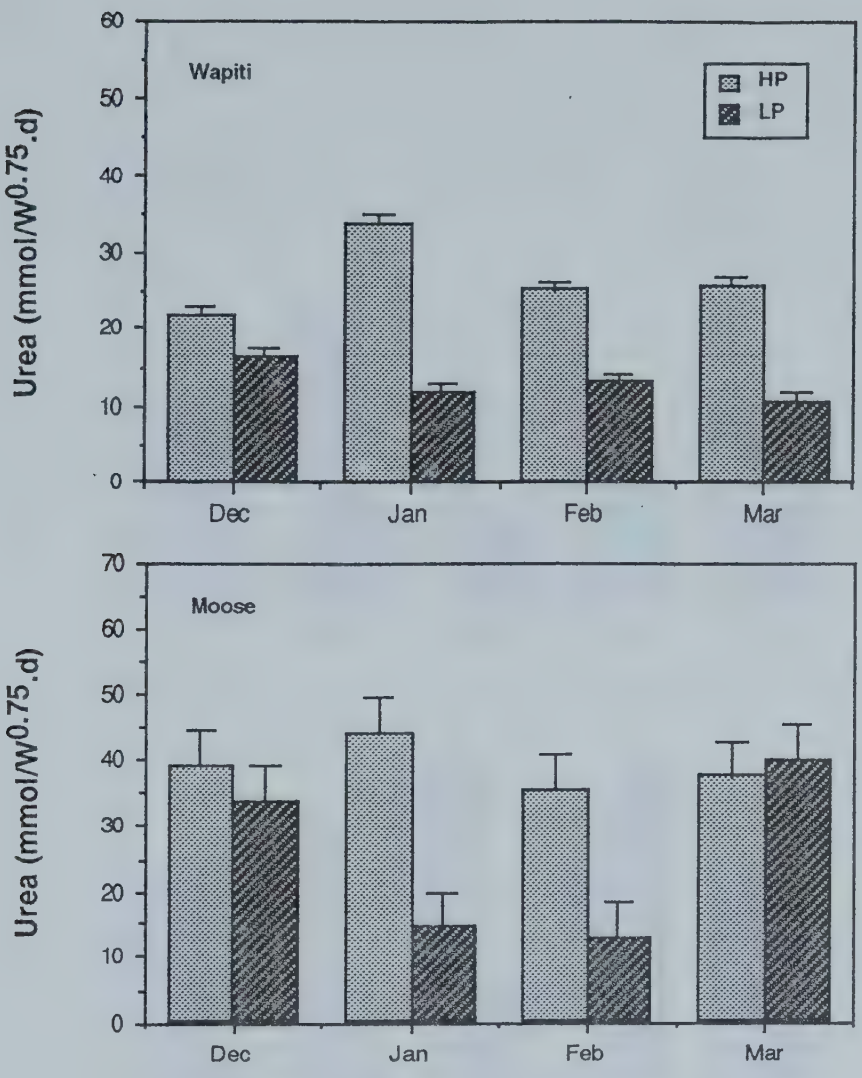


Figure 8. Daily urea nitrogen (mmol/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991. The data (mean±SE) are significantly different (P=0.05) from December to March for wapiti and from January to February for moose.

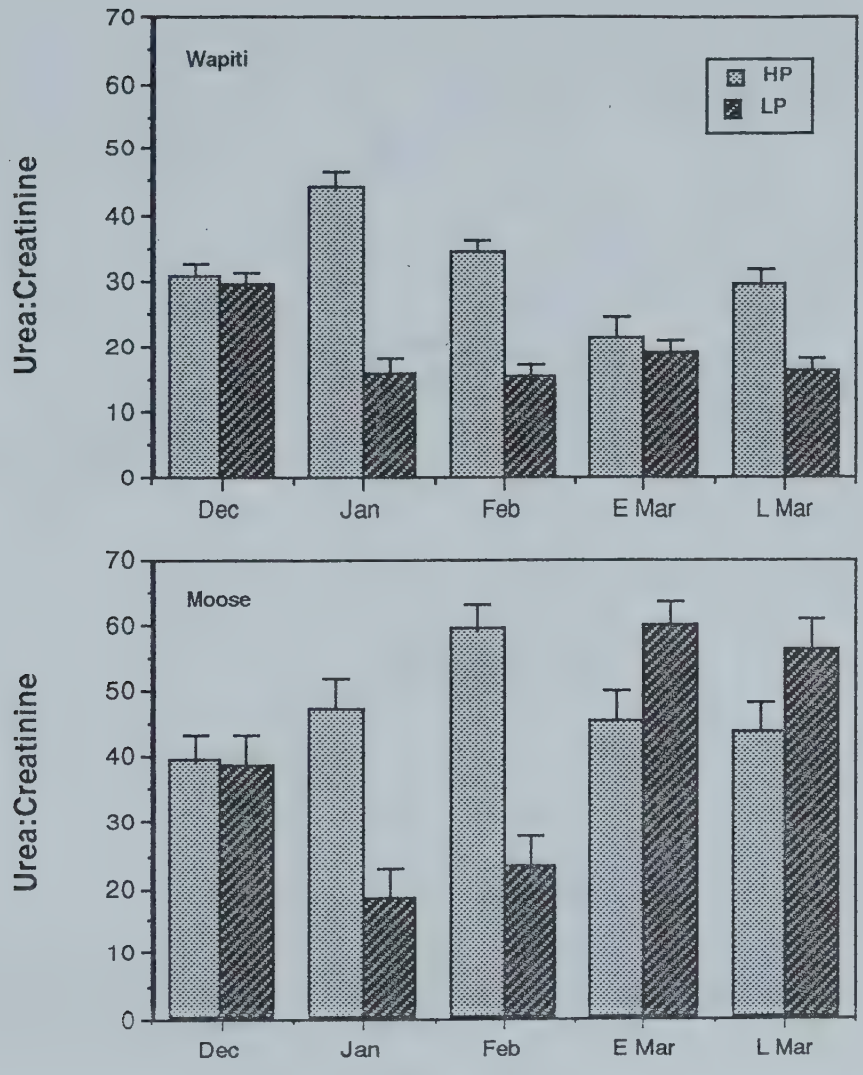


Figure 9. Urea:creatinine ratio (U/C) of 8 penned wapiti and 8 penned moose calves obtained from first urinations from December 1990 to March 1991. The data (mean±SE) are significantly different (P=0.05) between groups from January to early March for wapiti and moose.

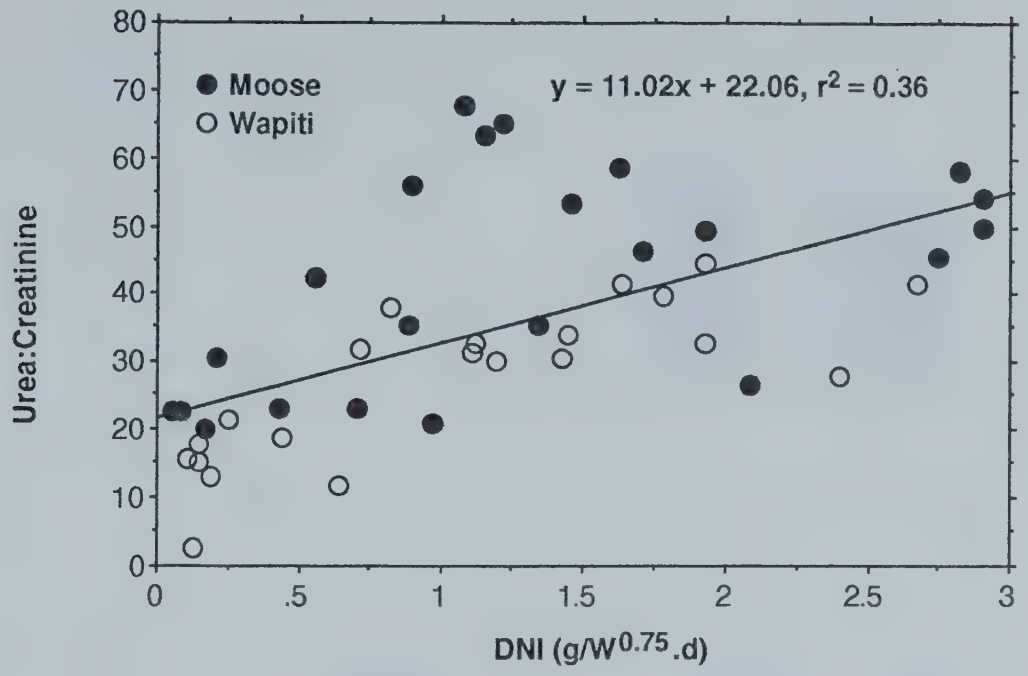


Figure 10. Relationship between digestible nitrogen intake (DNI) and urea:creatinine ratio (U/C), of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991.

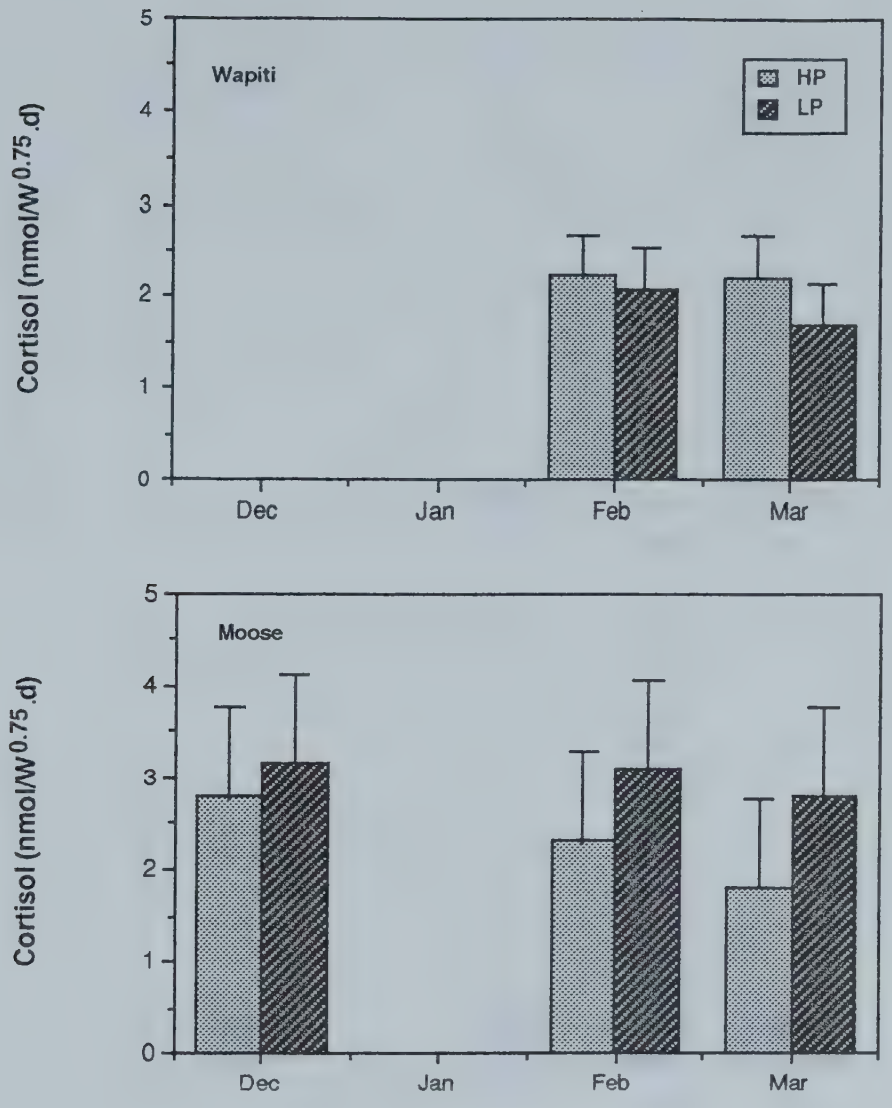


Figure 11. Daily cortisol excretion (nmol/$W^{0.75}$.d) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991. There were no significant differences (P=0.05) between groups for wapiti and moose. Missing data are denoted by blanks. The standard error is presented as a T over each bar.

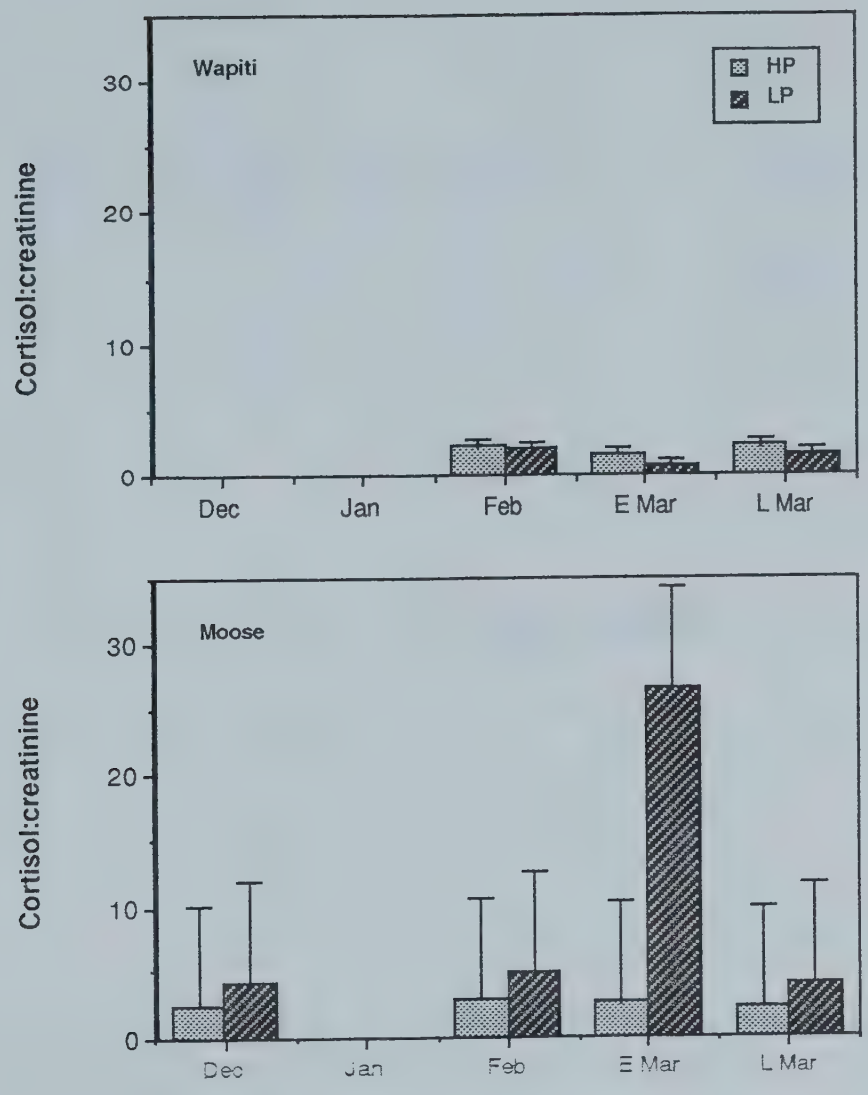


Figure 12. Cortisol:creatinine ratio (C/C) of 8 penned wapiti and 8 moose calves obtained from first urinations from December 1990 to March 1991. Missing data are denoted by blanks. The data (mean ± SE) are significantly different (P=0.05) between groups for early March for moose.

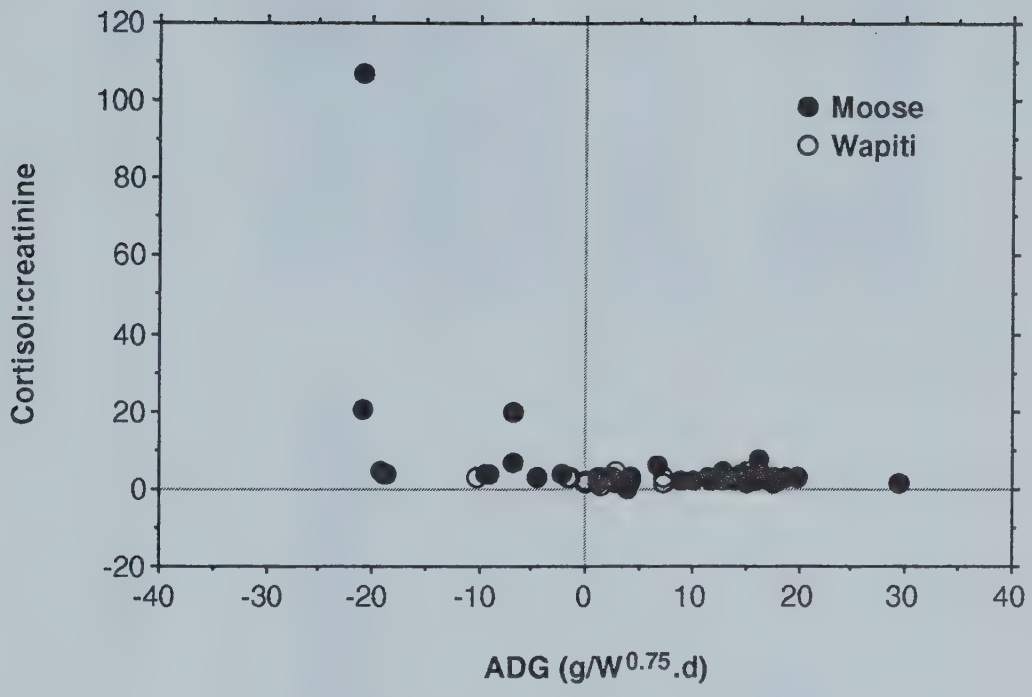


Figure 13. Relationship between average daily gain (ADG) and Cortisol:creatinine ratio (C/C) of 8 penned wapiti and 8 penned moose calves from December 1990 to March 1991.

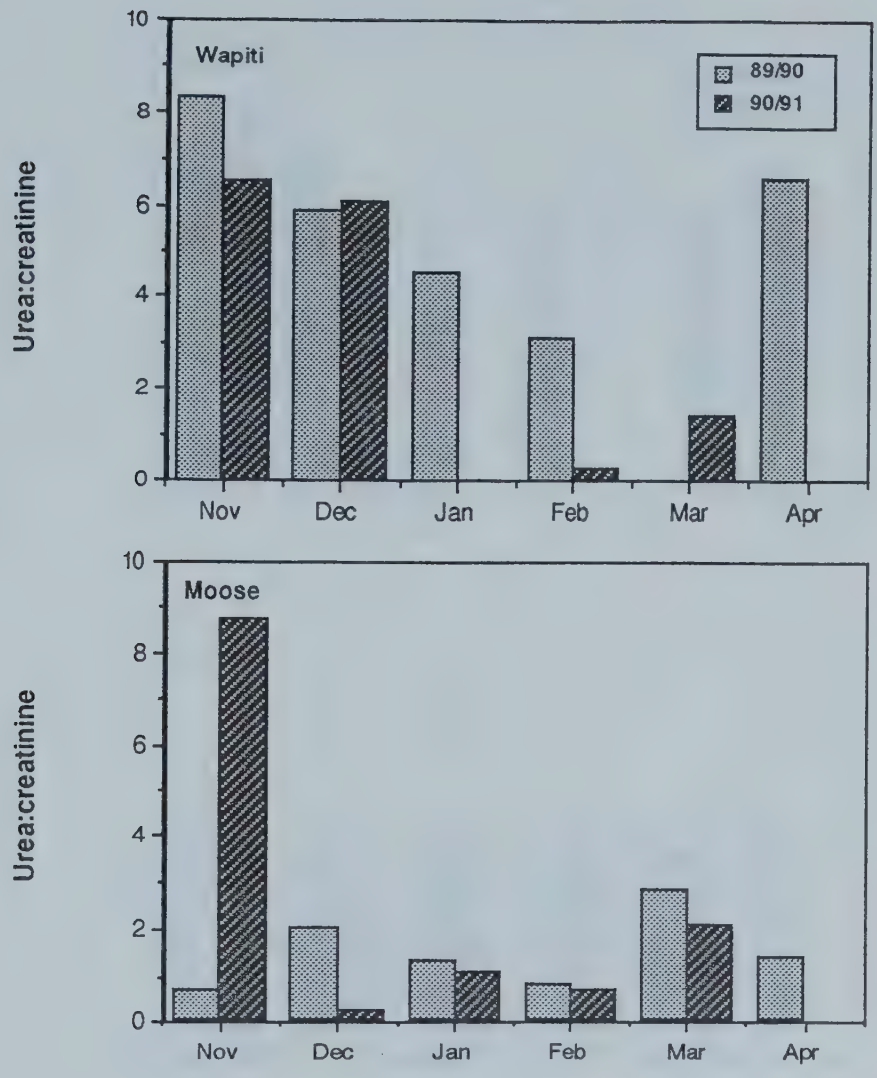


Figure 14. Urea:creatinine ratio (U/C) of wild wapiti and moose from Elk Island National Park obtained from November to April of 1989/90. The data are presented as Student-Newman-Keuls Means and are significantly different between years (P=0.05) for November, December and March for moose. Missing data are denoted by blanks.

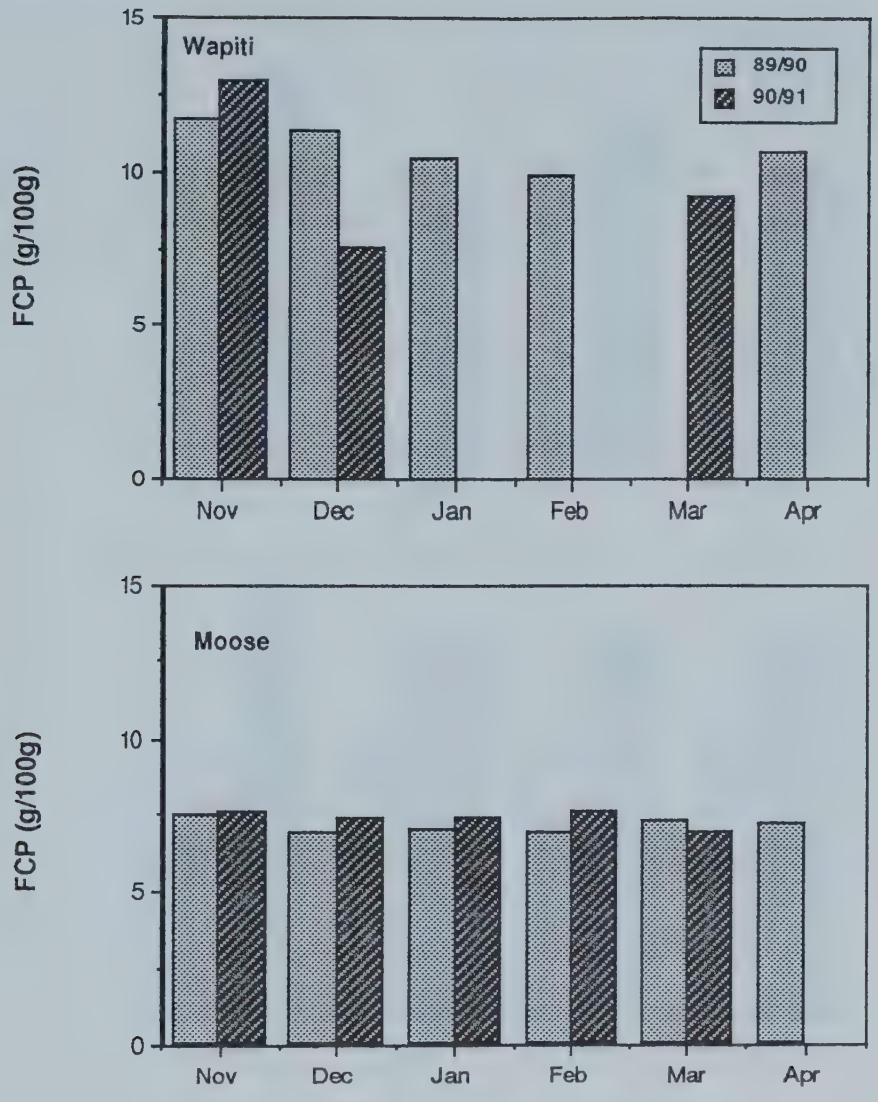


Figure 15. Fecal crude protein (FCP) of wild wapiti and moose from Elk Island National Park obtained from November to April of 1989/90 and 1990/91. The data are presented as Student-Newman-Kewls Means, and they are significantly different between years (P=0.05) for November and December for wapiti, and February for moose The missing data is denoted by blanks. The standard error is presented as a T over each bar.

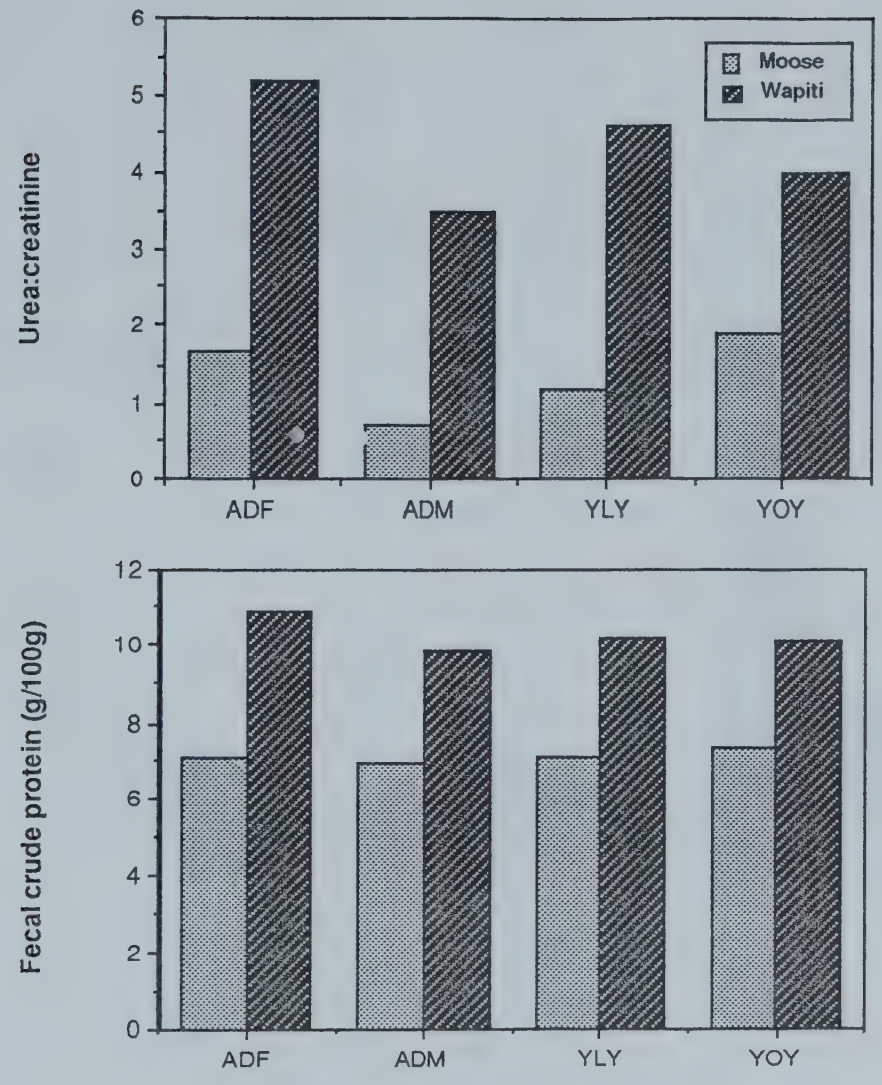


Figure 16. Age and gender differences in Urea:creatinine ratio (U/C) and fecal crude protein (FCP) in wild wapiti and moose from Elk Island National Park obtained from November to April of 1989/90 and 1990/91. The data are significantly different (P=0.05) between age and gender for adult male wapiti and adult male moose for U/C and FCP.

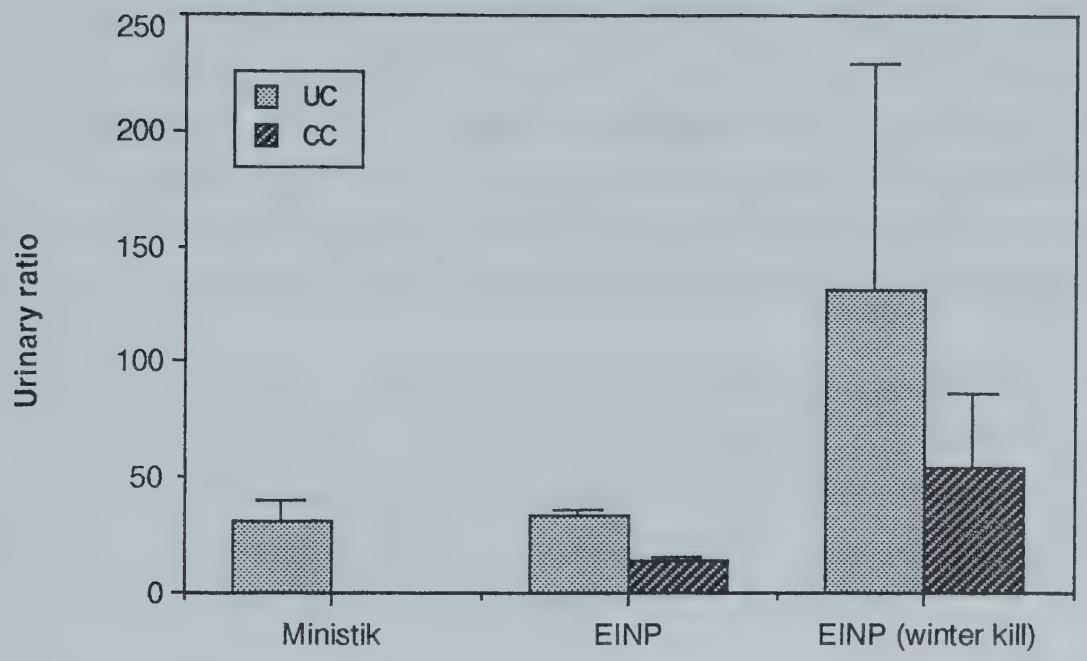


Figure 17. Urea:creatinine (U/C) and Cortisol:creatinine ratios of adult wapiti stags from Elk Island National Park and from the Ministik Wildlife Research Station obtained from snow urine in February 1990. No cortisol was detected in the wapiti stags from the Ministik Wildlife Research Station.

# 6.0 DISCUSSION

## 6.1 PERFORMANCE

### 6.1.1 Growth and Digestion

The LP moose had greater growth impetus than wapiti and continued to gain rapidly until February when feed was adjusted to 8.1% CP at 50% *ad libitum* intake. This may be an allometric penalty for this species because moose, being concentrate selectors (Hofmann 1973), must grow long limbs quickly to take advantage of dicotyledonous forages during winter. This also may explain why moose calves usually have smaller fat depots than other wild ruminants. LP moose digestion and growth responded to changes in diet quality which suggests that nutritional history affecting physiological status influenced the rebound of indices. Ruminants that fall short of their target weights also compensate by increasing forage intake relative to maintenance requirements (Watkins et al. 1991).

Generally, there was no marked difference in digestive efficiency between penned wapiti and moose fed a pelleted ration. Wapiti, moose and cattle maintained on the same diets also showed no detectable differences in fermentative capacities (Renecker and Hudson 1990). However, digestion in the wild will differ because of species specific patterns of forage selection and the propensity of mixed feeders to switch diets.

### 6.1.2 Requirements for Maintenance and Gain

Metabolizable energy requirements for maintenance for wapiti and moose in this study were similar to other estimates for wapiti and their smaller conspecific, the red deer. Previous studies at Ministik provided estimates of 572 $kJ/W^{0.75}.d$ for wapiti calves in winter (Jiang and Hudson 1992). In New Zealand, published estimates are 520 $kJ/W^{0.75}.d$ for penned red deer hinds and 570 $kJ/W^{0.75}.d$ for stags (Fennessy et al. 1981, Suttie et al. 1987). Values of 548 $kJ/W^{0.75}.d$ have been published for adult moose (Schwartz et al. 1988).

Metabolizable energy requirements for liveweight gain (27.0 kJ/g) for wapiti and moose were similar to 37.0 kJ/g for stags to 55.0 kJ/g for hinds and 26.0 kJ/g for wapiti during winter (Fennessy et al. 1981, Suttie et al. 1987, Jiang and Hudson 1992).

Corresponding digestible nitrogen intake requirements cannot be determined this way unless adequate energy is provided. Nevertheless, digestible nitrogen intake requirements

for maintenance for wapiti and moose (0.95 g/ $W^{0.75}$.d) were identical to those obtained by recalculating data for yearling wapiti from Westra (1978) (1.362 X 0.70 = 0.95 g/ $W^{0.75}$.d). This value is considerably higher than maintenance requirements for reindeer and caribou (0.46 g N $W^{0.75}$.d) (McEwan and Whitehead 1970).

## 6.2 CALIBRATION

### 6.2.1 Fecal Crude Protein

FCP was positively related to feed nitrogen in my study as in other studies of phenolic free rations (Mould and Robbins 1981). The lack of difference in regressions of FCP against DDMI, DNI and ADG between penned wapiti and moose calves suggests that digestion is similar given equal opportunity. Although FCP is potentially valuable as an index of diet quality, phenolic compounds capable of precipitating protein can give inaccurate estimates of nitrogen availability (Mould and Robbins 1981). Also, metabolic crises apparently can increase FCP as occurred in LP moose, although the increase may have been caused by urine contamination. Wapiti may be more efficient than moose at re-capturing nitrogen in the hind gut and hence lowering FCP. Other explanations for elevated FCP in moose are: a low dietary and or metabolic energy, high metabolic fecal nitrogen (gut epithelium, gut flora), highly indigestible ration that was propelled through the digestive tract, or a higher proportion of secondary compounds in LP rations which precipitated protein.

### 6.2.2 Urinary Creatinine

Creatinine excretion was relatively constant in animals that maintained body condition. Creatinine was unaffected by ambient temperature and its excretion rate was not significantly affected by fluctuations in daily urine volume. Diet and intake did not affect creatinine excretion until changes in live weight occurred. However, creatinine excretion was reduced for a brief period during February in HP moose, a time when weight gains were low or nil . A week before the collections, these animals were shivering in response to severe wind chills (-60 C). The reduced excretion rate of creatinine may have resulted from a recovery of creatine phosphate in muscle tissue due to stress. In humans, changes in plasma volume affected creatinine excretion. More specifically, strenuous exercise and environmental stress resulting in dehydration can lead to diminished creatinine excretion (Schutte et al. 1981).

Creatinine is the sole metabolite of creatine. Creatine is usually bound as creatine phosphate and about 98% of it is located in the striated muscles of humans (Schutte et al.

1981) where it act as a phosphate donor for the phosphorylation of adenosine diphosphate (ADP) during muscle action. Once creatine phosphate is dephosphorylated, it is dehydrated to creatinine and excreted through the kidney.

Urea:creatinine ratios were very sensitive to changes in physiological status and elevated cortisol:creatinine ratios reflected a progressive use of endogenous tissue. A decrease in creatinine excretion in animals that are losing muscle mass, or recovering from a loss of muscle, decreases the creatinine denominator and elevates the ratio. This may be compounded by rising endogenous nitrogen sources (numerator) in animals catabolizing tissue. This is evident when daily urea nitrogen excretion is compared to U/C ratios. The U/C ratios begin rising in January in LP moose which is evidence of animals catabolizing tissue, whereas daily urea nitrogen excretion appeared unchanged.

### 6.2.3 Urinary Urea and Cortisol

Wapiti and moose calves on high quality diets excreted more urea and had higher U/C ratios, corroborating other studies. White-tailed deer on low protein diets and on 25% food restriction had lower U/C ratios (Warren et al. 1982). Supplementally fed deer also had higher U/C ratios than deer on winter range (Delgiudice et al. 1989). Although DDMI was greater on HP diets, its effect on urea excretion was not significant. A 50% reduction in voluntary intake and fasting in LP groups in February did not reduce urea excretion as anticipated. This was contrary to studies carried out on deer. Warren et al. (1982) and Hove and Jacobson (1975) found that urea excretion decreased due to recycling when animals were placed on restricted intake. An increased source of endogenous nitrogen contributing to the daily urea excretion may have masked the effect in LP groups. Cortisol excretion and C/C ratios were relatively constant during winter except in early March when C/C ratios in LP moose were very high. The content of cortisol in urine samples was very high in several LP moose.

The increase in cortisol can also be explained as follows. The free form of cortisol secreted into the blood is usually bound by specific corticosteroid-binding globulin (transcortin) which makes it less filterable through the glomerulus of the kidney (Beisel et al. 1964). When large amounts of cortisol are released due to a hypertrophy of the adrenal cortex or to an increase response mediated by adrenocorticotropic hormone (ACTH), all of the transcortin is saturated and the amount of free cortisol excreted into the urine increases.

The increased circulating nitrogen and energy substrates during this time are due to cortisol's ability to potentiate gluconeogenesis and mobilise proteins (Guyton 1976). Cortisol's ability to reflect an energy deficit was reported in deer fawns (Saltz and White 1991a). Holter et al. (1977) also reported elevated urinary nitrogen in deer fawns on diets low in protein. An exponential rise in cortisol was also reported during the transitional stages of starvation, from stage II (period when fat stores are being depleted due to a limited supply of dietary crude protein) (Torbit et al. 1985), to stage III depicted by excessive muscle catabolism (Robinson and Williamson 1980).

The high snow urine U/C and C/C ratios observed in wapiti stags corralled at Elk Island National Park for over two months also support this claim. Some of these wapiti were emaciated and 2 of 30 stags subsequently died. These animals were relocated to the Yukon, radio-collared and successfully released to the wild. The wapiti that died had very high snow urine U/C and C/C ratios. In contrast, no cortisol was recovered in snow urine from well-fed captive wapiti stags at the Ministik Wildlife Research Station.

High U/C ratios obtained from bladder urine were also reported by Delgiudice et al. (1991) in dead wapiti and moose. Mean U/C ratios were from 73.5 (SE = 30.5) to 30.3 (SE = 9.2) for wapiti and 26.7 (SE = 9.6) for moose. The elevated urinary indices in dead animals are evidence of catabolism, although leakage into the vascular system and bladder due to tissue degeneration also contribute.

Chronic infections may have marginally elevated urinary cortisol although it was not statistically significant. In these circumstances, a rise in cortisol could be a response to infection rather than nutrition. Aside from its ability to potentiate catabolic activity and mobilise fat and protein, urinary cortisol may become elevated during chronic disease because it suppresses inflammation by stabilizing lysosomes (Guyton 1976). Cortisol production also responds to population density (Saltz and White 1991a) and may be elevated in highly populated areas and where rangeland is patchy. High C/C levels of corralled wapiti may have initially been due to stress of confinement.

When collecting cortisol it is important to note the body condition. Chronic winter diseases such as winter ticks in moose or liver flukes in wapiti may elevate urinary cortisol, initially as a response to disease and later in response to negative nitrogen and energy balance.

Blood cortisol levels are high in the morning and taper off during the evening. Urinary cortisol in this case offers a more reliable assessment since urine can accumulate for several hours in the bladder, dampening the diurnal effect (Saltz and White, 1991a). The diurnal effect of cortisol may be dampened by continuous secretions of cortisol into the blood stream. The increase in cortisol can be from a hypertrophy of the adrenal cortex or in response to an increased demand in gluconeogenesis.

## 6.3 FIELD APPLICATION

Both winters were moderate with snow depths never exceeding 30 cm and temperatures below - 15 C never lasted more than a week. No significant losses to wapiti and moose populations occurred in Elk Island National Park during the study.

The small magnitude of change in U/C ratios during these winters reflected animals that maintained body condition compared to the significant changes in urinary indices noted in LP groups during the pen trials. Several U/C ratios were above 8 for each age and gender class for each species during the winter. This is normal because a certain percentage of animals (usually the very young or old) succumb to winter. The relative absence of cortisol in snow urine in late winter also indicated generally good conditions in 1990/91.

Both U/C and FCP followed similar declining patterns during the winter and reflected changes in nitrogen availability. Significant differences were noted in wapiti and moose U/C and FCP; moose having lower U/C and FCP. This difference is related to the partitioning of resources. Wapiti select foods, mainly graminoids that are higher in CP content and more digestible than browse selected by moose (Appendix 4). Retention times are also slower for grasses (Renecker and Hudson 1990) allowing for enhanced fermentation which may account for a spill-over of nitrogen into the urine and feces. In contrast, browse consumed by moose is rapidly propelled through the rumen (Demment 1982, Renecker and Hudson 1990). A higher digestive capacity and higher fermentation rate in wapiti reported by Van Hoven and Boomker (1985) was due to diet selection. Smaller ruminants also have higher total fecal nitrogen losses because of higher fermentation rates, greater bacterial nitrogen and larger surface-to-volume ratio in the alimentary tract (Arman et al. 1975). Wapiti also adapt to changes in diet quality by re-arranging the mucosal surface of the rumen, which reduces or enlarges the absorptive surface (Hofmann 1973). Free ranging wapiti and related cervids such as red deer also have higher turnover and fermentation rates than moose. Volatile fatty acid (VFA)

concentration was much higher in red deer (10.64 mmol/100 ml) than moose (6.5 mmol/100 ml) (Van Hoven and Boomker 1985). This difference can also be attributed to diet selection.

Dietary protein was generally lower in wild forages (Appendix 7) and contributed to a lower urea excretion and FCP. When crude protein in the diet falls below 8%, the digestive efficiency of the rumen declines due to shortage of nitrogen for rumen microbial functions (Van Soest 1982). Pelleting and the inherent differences in gut fill, food particle size, retention times and fermentation rates would also account for relatively higher values in penned animals. The costs of searching for food, filling the gut and a coarse fibrous diet would also result in higher nitrogen and energy demands for maintaining body functions in free ranging ruminants.

The lower FCP in moose also raises questions of the effect of plant secondary compounds on protein digestion. Because moose browse almost exclusively on dicotyledonous forages high in secondary compounds (Schwartz and Hobbs 1985) one would expect some variability in FCP as compared to wapiti. This was not the case in my study, so I question the importance of these plant antifeedants. In both study years, these did not appear to interfere with fat accretion during summer and fall or with animals meeting their maintenance requirements during winter.

A colder winter with deeper and more persistent snow cover in early December 1990 compounded by an increase in browsing pressure and higher animal numbers resulted in lower U/C and FCP except that moose FCP were higher in 1989/90. The lower U/C ratios and FCP (for wapiti) in the second year can be explained by a reduction in food, reducing DMI, switching diets lower in CP, and possibly an increase in nitrogen recycling. Cold temperatures also increase the digestion of protein in the hindgut in domestic animals (Kennedy and Milligan 1978). In this case, nitrogen recycling can be enhanced, although the amount of recycling that occurs here in wild ruminants is uncertain (Nolan and Stachiw 1979, Mould and Robbins 1981). A wild ruminant that is less efficient at re-capturing nitrogen in the lower digestive tract would also lose a significant amount of nitrogen through the feces.

By March of both years, a gradual rise in both U/C and FCP coincided with warmer temperatures and a reduced snow cover. Although the absence of cortisol in snow urine in

1990/91 did not suggest advanced catabolism, rising U/C ratios may have been caused by tissue catabolism, lowering the creatinine denominator.

Free ranging wild ruminants during the later stages of starvation (catabolism of body protein) also may show elevated FCP during late winter. This may have been the case for several adult male wapiti that died with unusually high FCP at Elk Island National Park in 1984. Initially, a rapid drop in FCP in late October for wapiti was due to wapiti eating more browse because of a freezing snowfall. By mid to late November, FCP values were unusually high in these individuals and they appeared to be in poor body condition. Elevated FCP also may reflect an increase in metabolic fecal nitrogen due to coarse browse.

Wapiti stags and bull moose had lower FCP and U/C ratios. Bulls expend considerable energy and lose weight during the rut and enter winter in poor condition. They also feed less selectively. Thus, lower quality forage would lead to reduced nitrogen excretion. An animal in poorer condition may have less microbial matter and less non ammonia nitrogen (NAN) escaping into the hind gut. This would also lower FCP and U/C. Similar findings are reported by Gates and Hudson (1981). Animals losing more weight during winter had lower FCP. Adult males also excrete more creatinine because of their larger body mass hence lowering the U/C ratio.

In this study, the lack of difference of indices between calves and adult females must be addressed because females are larger and in better condition than moose calves. This lack of difference could be due to rising U/C ratios in calves due to enhanced tissue catabolism. Calves may also have higher fermentation rates and a larger surface to volume ratio in the rumen (Appendix 5). Moose calves were also in much poorer condition than other moose, wapiti and deer. Although their rumen crude protein and fecal crude protein and blood urea nitrogen remained high, moose calves had no backfat or kidney fat, and femur marrow fat was reduced to 40% for 2 calves by the end of March. Unfortunately, urine samples were not analyzed for cortisol, although these animals did not appear to be in the latter stages of starvation and no losses to this cohort was evident in either winter.

## 7.0 MANAGEMENT IMPLICATIONS

Urinations must also clearly be distinguished according to species because of the differences in diet selection affecting digestive capacity, rumen efficiency (rumen fermentation rate, adaptability to changes in retention time of food) energy and nitrogen requirements, and differences in nitrogen usage (re-cycling). The age and gender of animals also should be recorded for each urination because animals of different age and gender classes vary greatly in muscle mass and urinary creatinine excretion will vary accordingly. Animals varying in age and gender will also be in different states of nutritional and physiological condition during winter.

The sequential collection of snow urine is important, especially when nitrogen use is being monitored through U/C ratios. When nitrogen excretion reaches its lowest point (February in normal winters) due to a declining forage quality and/or availability and nitrogen recycling is at its highest, this can be termed the critical threshold (Schwartz et al. 1988). Monitoring for this threshold reveals an increased demand on body reserves and an overall decrease in the condition of a population. An early reversal of indices when range is still a limiting factor may indicate progressive tissue catabolism. The initial rise in U/C ratios would be attributed to a diminished creatinine excretion rate, denoting a loss of lean tissue. However, set points may vary within normal ranges. U/C ratios fluctuating between 0 and 8 would be considered normal during early winter for wild wapiti and moose. However, calves may already be in poor condition when ratios are close to 8. Fluctuations are best explained by changes in flux rates through the glomerulus in response to temperature or to changes in diet quality and forage selection generally affecting digestive kinetics.

U/C and C/C ratios over of 30.0, and 10.0 respectively, clearly reflected a metabolic deficit of energy and nitrogen for penned wapiti and moose calves. These ratios indicate lean animals losing body weight at over 5 grams/kg B $W^{0.75}$/d. Snow urine cortisol was only detected in animals that were in poor condition. The use of snow urine C/C is then limited for monitoring progressive changes in energy reserves in wild wapiti and moose for the following reasons.

Trace amounts of cortisol excreted from the kidney compounded by dilution of snow urine and the sensitivity of the radioimmunoassay procedure (< 10 nm/l) limit its use.

This was evident when only 1 out of 90 snow urine samples collected from November to March of 1990/91 showed trace amounts of cortisol. Cortisol may only become detectable in snow urine when cortisol responds exponentially although it does not mean that death is eminent. Rather it distinguishes the extent of tissue catabolism occurring in lean bodied animals. It also distinguishes elevated urinary nitrogen brought about by tissue catabolism from an increase in dietary protein. The former may forewarn of mortality.

Fecal crude protein was a reliable indicator of forage quality and availability of nitrogen, although it was a less sensitive measure of physiological status. A rise in FCP during winter coincided with wapiti stags at Elk Island and wapiti and moose calves at Ministik observed to be in poor condition. This relationship requires further confirmation.

The response of cortisol and urea excretion to chronic disease such as heavy winter moose tick and giant liver fluke infestations and to severe weather requires investigation. More work is also required to assess the response of macro mineral excretion and cortisol. Preliminary work shows a significant rise in calcium and phosphorous in moose calves in poor condition. (Appendix 6).

The use of U/C and C/C ratios show promise for monitoring the nutritional and physiological status of wild ruminants. Cortisol in snow urine is clear evidence of negative energy balance and of a progressive deterioration of muscle mass. Often visual signs such as pronounced angulation of the rump and general emaciation are evident, a time when indices such as cortisol are not required for assessing body condition. However physical evaluation in the field is subjective, not always possible and false evaluations are often masked by other causes such as hair loss. The exponential increase of cortisol regardless of metabolic mass may obviate the need to relate age and gender to urinations. This technique would be useful when the association of age and sex to specific urinations cannot be determined. When sequential collections are not practised, one time collection of snow urine samples from a population in mid winter and subsequent analysis for U/C and C/C would give a reasonable assessment of a populations nitrogen and energy balance.

This study demonstrated the need to associate urinations to age and gender when monitoring U/C ratios as well as the inherent nutritional requirements and physiological differences that exist between age and gender classes and between species.

## 8.0 LITERATURE CITED


Abbott, M.J., D.E. Ullrey, K.K. Pao, S.M. Schmitt, D.R. Romsos, and H.A. Tucker. 1984. Effect of photoperiod and fat accretion in white-tailed deer doe fawns. J. Wildl. Manage. 48: 776-787.

A.O.A.C. 1965. *Official methods of analysis.* 10th Ed. Association of Official Agriculture Chemists. Washington, D.C.

Arman, P., D. Hopcraft, and I. Mcdonald. 1975. Nutritional studies on East African herbivores. 2. Losses of nitrogen in the faeces. Br. J. Nutr. 32: 669-686.

Baker, D.L., and N.T. Hobbs. 1985. Emergency feeding of mule deer during winter: tests of a supplemental ration. J. Wildl. Manage. 49: 934-942.

Beisel, W.R., J.J Cos, R. Horton, P.Y. Chao, and P.H. Forsham. 1964. Physiology of urinary cortisol excretion. J. Clin. Endocrinol. 24: 887-

Blaxter, K.L., J.L. Clapperton, and A.K. Martin. 1966. The heat of combustion of the urine of sheep and cattle in relation to its chemical composition and to diet. Brit. J. Nutr. 20: 449-460.

Chao, C.C., and R.D. Brown. 1984. Seasonal relationships of thyroid, sexual and adrenocortical hormones to nutritional parameters and climatic factors in white-tailed deer (*Odocoileus virginianus*) of South Texas. Comp. Biochem. Physiol. 77: 229-306.

Coles, E.H. 1980. *Veterinary clinical pathology*. 4th ed. W.B. Saunders Co. Philadelphia, Pa.

Dalton, R.G. 1967. The effect of starvation on the fluid and electrolyte metabolism of neonatal calves. Br. Vet. J. 123: 237-245.

deCalesta, D.S., J.G. Nagy, and J.A. Bailey. 1974. Some effects of starvation on mule deer rumen bacteria. J. Wildl. Manage. 38: 815-822.

Delgiudice, G. D., L. D. Mech, and U. S. Seal. 1989. Physiological assessment of deer populations by analysis of urine in snow. J. Wildl. Manage. 53: 284-291.

Delgiudice, G. D., U.S. Seal, and D.L. Mech. 1991. Indicators of severe undernutrition in urine of free-ranging elk during winter. Wildl. Soc. Bull. 19: 106-110.

Demment, M.W. 1982. The scaling of ruminoreticulum size with body weight in East African ungulates. Afr. J. Ecol. 20:43-47.

Fennessy, P.F., G.H. Moore and J.D. Corson. 1981. Energy requirements of red deer. N. Z. Soc. Anim. Prod. 41: 167-173.

Franzman, A.W., and R.E. LeResche. 1978. Alaskan moose blood studies with emphasis on condition evaluation. J. Wildl. Manage. 42: 334-351.

Gates, C. C., and R. J. Hudson. 1981. Weight dynamics of wapiti in the boreal forest. Acta. Theriol. 26, 27: 407-418.

Goering, H.K., and P.J. Van Soest. 1970. Forage fibre analysis (apparatus, reagents, procedures and some applications). U.S. Dept. Agr., Agric. Handbk.

Guyton, A.C. 1976. *Textbook of medical physiology*. 5th ed. W.B. Saunders Co., Philadelphia, Pa.

Hobbs, N.T. 1989. Predicting starvation in mule deer: development and test of a simulation model. Wildl. Monogr. 101: 1-39.

Hofmann, R.R. 1973. *The ruminant stomach. Stomach structure and feeding habits of East African game ruminants*. East African Monographs in Biology, vol 2, East Afr. Lit. Bur.

Holter, J.B., W.E Urban, and H.H. Hayes. 1977. Nutrition of northern white-tailed deer throughout the year. J. Anim. Sci. 45: 365-376.

Hove, K., and E. Jacobsen. 1975. Renal excretion of urea in reindeer. Effect of nutrition. Acta vet. Scand. 16: 513-519.

Hudson, R. J., and R. J. Christopherson. 1985. Maintenance metabolism. Pages 121-142 in R. J. Hudson., and R. G. White (ed.). *Bioenergetics of wild herbivores*. CRC Press, Boca Raton, Fla.

Jiang, J., and R.J. Hudson. 1992. Estimating forage intake and energy requirements of free-ranging wapiti (*Cervus elaphus*). Can. J. Zool., in press.

Kennedy, P.M., L.P. Milligan. 1978. Effects of cold exposure on digestion, microbial synthesis and nitrogen transformation in sheep. Br. J. Nutr. 39: 105-117.

Klasig. K C. 1985. Influence of stress on protein metabolism. Pages 269-280 in G.P. Moberg (ed.) *Animal stress*. Am. Physiol. Soc., Bethesda, Md.

Leslie, D.M. Jr., and E.E. Starkey. 1985. Fecal indices to dietary quality of cervids in old-growth forests. J. Wildl. Manage. 49: 142-146.

McEwen, E.H., and C.E. Whitehead. 1970. Seasonal changes in energy and nitrogen intake in reindeer and caribou. Can. J. Zool. 48: 905-913.

Mitchell, B., D. McCowan, and I. A. Nicholson. 1976. Annual cycles of body weight and condition in Scottish red deer (*Cervus elaphus*) J. Zool. 180: 107-127.

Mould, E. D., and C. T. Robbins. 1981. Nitrogen metabolism in elk. J. Wildl. Manage. 45: 323-333.

Nolan, J.V., and S. Stachiw. 1979. Fermentation and nitrogen dynamics in merino sheep given a low-quality-roughage diet. Brit.J. Nutr. 42: 63-80.

Olson, R. 1985. *The climate of Edmonton*- Climatological Studies No. 37, The climate of Canadian cities No. 2, Environment Canada, Ottawa.

Owen, O.E., P. Felig, A.P. Morgan, J. Wahren, and G.F. Cahill, Jr. 1969. Liver and kidney metabolism during prolonged starvation. J. Clin. Invest. 48: 574-583.

Renecker, L.A., and R.J. Hudson 1990. Digestive kinetics of moose (*Alces*), wapiti (*Cervus elaphus*) and cattle. J. Anim. Prod. 50: 51-61.

Riney, T. 1955. Evaluating condition of free-ranging red deer (*Cervus elaphus*), with special reference to New Zealand. N. Z. J. Sci. Technol. 36: 429-463.

Robbins, C.T., P.J. Van Soest, W.W. Mautz, A.N. Moen. 1975. Feed analyses and digestion with reference to white-tailed deer. J. Wildl. Manage. 39: 67-79.

Robinson, A.M., and D.H. Williamson. 1980. Physiological roles of ketone bodies as substrates and signals in mammalian tissues. Physiol. Rev. 60: 143-187.

Saltz, D., and G.C. White. 1991a. Urinary cortisol and urea nitrogen responses in irreversibly undernourished mule deer fawns. J. Wildl. Diseases 27: 41-46.

Saltz, D., and G.C. White. 1991b. Urinary cortisol and urea nitrogen responses to winter stress in mule deer. J. Wildl. Manage. 55: 1-16.

Sauberlich., H. E., R. P. Dowdy, and J. H. Skala. 1973. Laboratory tests for the assessment of nutritional status. Crit. Rev. Clin. Lab. Sci. 4:215-340.

Seal, U. S., L. J. Verme, and J. J. Ozoga. 1978. Dietary protein and energy effects on deer fawn metabolic patterns. J. Wildl. Manage. 42: 776-790.

Scutte, J.E., J.C. Longhurst, F.A. Gaffney, B.C. Bastian, and C.G. Gunnar. 1981. Total plasma creatinine: an accurate measure of total striated muscle mass. Physiol. Soc. 161: 762-766.

Schwartz, C.C., W.L. Regelin, and A.W. Franzman. 1984. Seasonal dynamics of food intake in moose. Alces. 20: 223-244

Schwartz, C.C., and T.N. Hobbs. 1985. Forage and range evaluation. Pages 25-52 in R.J. Hudson and R.G. White (ed.). *Bioenergetics of wild herbivores*. CRC Press, Boca Raton, Fla.

Schwartz, C. C., M. E. Hubert, and A. W. Franzman. 1988. Energy requirements of adult moose for winter maintenance. J. Wildl. Manage. 52: 26-33.

Suttie, J.M., P.F. Fennessy, B.A. Veenvliet, R.P. Littlejohn, M.W. Corson and R.E. Labes. 1987. Energy nutrition of young red deer (*Cervus elaphus*) hinds and a comparison with young stags. N. Z. Soc. Anim. Prod. 47: 111-113.

Swift, D.M. 1983. A simulation model of energy and nitrogen balance for free-ranging ruminants. J. Wildl. Manage. 47: 620- 645.

Thorton, R.F., and B. W. Wilson. 1972. Factors affecting the urinary excretion of urea nitrogen in cattle. II. High plasma urea nitrogen concentrations. Aust. J. Agric. Res. 23: 727-734.

Topps, R.C., and J.H. Elliot. 1964. Studies of protein requirements of ruminants. Nitrogen trials on blackhead sheep given diets of different energy and protein content. Brit. J. Nutr. 18: 245-252.

Torbit, S. C., L. H. Carpenter, D. M. Swift, and A. W. Aldredge. 1985. Differential loss of fat and protein by mule deer. J. Wildl. Manage. 49: 80-85.

Van Hoven, W., and E.A. Boomker. 1985. Digestion. pages 103-117 in R.J. Hudson, and R.G. White (eds.). *Bioenergetics of wild herbivores* CRC Press, Boca Raton, Fla.

Van Keulen, J., and B.A. Young. 1977. Evaluation of acid insoluble ash as a natural marker in ruminant digestibility studies. J. Anim. Sci. 44: 282-287.

Van Soest P.J. 1982. *Nutritional ecology of the ruminant*.. O&B Books. Inc. Corvalis, Oregon.

Verme, L.J., and J.J. Ozoga. 1980. Effects of diet on growth and lipogenesis in deer fawns. J. Wildl. Manage. 44: 315-324.

Vestergaard, P., and R. Leverett. 1958. Constancy of urinary creatinine excretion. J. Lab. Clin. Med. 51: 211-218.

Waid, W. D., and R. J. Warren. 1984. Seasonal variations in physiological indices of adult female white-tailed deer in Texas. J. Wildl. Dis. 20: 212-219.

Wallmo, O.C., L.H. Carpenter., W.L. Regelin, R.B. Gill, and D.L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. J. Range Manage. 30: 122-127.

Warren, R.J., R.L. Kirkpatrick, A. Oelschlaeger, P.F. Scanlon, and F.C. Gwazdauskas. 1981. Dietary and seasonal influences on Nutritional indices of adult male white-tailed deer. J. Wildl. Manage. 45: 926-936.

Warren, R. J., R. L. Kirkpatrick, A. Oelschlaeger, P. F. Scalon, K. E Webb, Jr., and J. B. Whelan. 1982. Energy protein and seasonal influences on white tailed deer fawn nutritional indices. J. Wildl. Manage. 46: 302-312.

Watkins W.G., R.J. Hudson, and P.L.J. Fargey 1991. Compensatory growth of wapiti *(Cervus elaphus)* on aspen parkland ranges. Can. J. Zool. 69: 1682-1688.

Westra, R. 1978. The effect of temperature and season on the digestion and urea kinetics in growing wapiti. Ph.D. Thesis, Univ. Alberta, Edmonton, Alberta.

Yousef, M.K., and H.D. Johnson. 1967. Calorigenesis of cattle as influenced by hydrocortisone and environmental temperatures. J. Anim. Sci. 26: 1087-1093.

Zoltai, S.C. 1975. Southern limit of coniferous trees on the Canadian plain. Environ Canada, Forestry Service., Northern Forest Res. Centre, Edmonton, Alberta.

# APPENDICES

APPENDIX 1. Wapiti and moose calf information.

| NAME ALFLEX# | EAR TAG# | SPECIES | GENDER | ACQUIRED | ORIGIN |
|---|---|---|---|---|---|
| FAWN-03 | 0122 | WAPITI | FEMALE | JUNE 28 | MINISTIK |
| FRED-06 | 0114 | " | MALE | MAY 24 | " |
| FLOWER-30 | 0112 | " | FEMALE | JUNE 30 | " |
| FLICKER-36 | 0113 | " | FEMALE | JUNE 30 | " |
| FANDANGO-38 | 0116 | " | MALE | JUNE 30 | " |
| FLORIDA-39 | 0117 | " | FEMALE | JUNE 30 | " |
| FLAME-40 | 0115 | " | MALE | JULY 05 | " |
| FELIX-31 | _____ | " | MALE | SEP 10 | " |
| BUD-01 | 0127 | MOOSE | MALE | MAY 24 | EINP |
| BETSY-02 | 0124 | " | FEMALE | MAY 25 | WHITECOURT |
| CHARLEY-03 | 0126 | " | MALE | MAY 28 | EINP |
| WISKEY-04 | 0119 | " | FEMALE | MAY 28 | WHITECOURT |
| LUCY-05 | 0120 | " | FEMALE | MAY 30 | EINP |
| JAKE-06 | 0125 | " | MALE | MAY 30 | GR. PRAIRIE |
| MISTY-07 | 0123 | " | FEMALE | JUNE 1 | ATHABASCA |
| DANCER-08 | 0128 | " | FEMALE | JUNE 8 | COOKING LAKE |
| BUCK-09 | 0118 | " | MALE | JUNE 19 | DRAYT.VALLEY |

APPENDIX 2. Fat, protein and lactose content of milk formulas fed to wapiti and moose calves.

| | % | | |
|---|---|---|---|
| | FAT | PROTEIN | LACTOSE |
| *DAIRY MILK + 50% LMR | 4.83 | 4.90 | 8.05 |
| HOMO MILK+ 50% LMR | 4.95 | 4.78 | 7.88 |
| DAIRY MILK | 3.60 | 3.13 | 4.86 |
| WATER + 50% LMR | 1.78 | 1.49 | 2.86 |
| LMR(POWDER) | 30.0 | ^24.0 | - |

* = choice mixture

LMR = canadian nurs-ette deluxe lamb milk replacer

^ = an additional 24% crude protein from milk by-products

NB: analysis of milk mixtures carried out by the provincial laboratory services branch, Edmonton, Alberta.

APPENDIX 3. Moose and wapiti calf feeding and weaning schedule.

MOOSE ALFLEX EAR TAG #

| WEEK | | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | * | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 |
| | ** | 1.92 | 1.47 | 1.59 | 1.63 | 1.67 | 2.44 | 2.51 | 2.44 | 2.06 |
| 2 | | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 |
| | | 1.90 | 2.58 | 1.87 | 1.92 | 2.07 | 2.94 | 2.99 | 3.18 | 2.75 |
| 3 | | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 |
| | | 2.59 | 2.99 | 2.14 | 2.14 | 2.42 | 3.01 | 3.38 | 3.21 | 2.66 |
| 4 | | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | | 3.23 | 3.55 | 2.74 | 2.89 | 3.06 | 4.00 | 4.00 | 4.00 | 2.97 |
| 5 | | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 |
| | | 3.95 | 3.81 | 3.33 | 3.68 | 3.09 | 4.00 | 4.00 | 3.54 | 3.39 |
| 6 | | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| | | 4.00 | 3.77 | 3.88 | 4.00 | 3.62 | 3.77 | 3.54 | 3.20 | 3.65 |
| 7 | | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 4 | 4 |
| | | 3.54 | 3.43 | 4.00 | 3.20 | 3.85 | 3.20 | 2.86 | 2.74 | 3.20 |
| 8 | | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 4 |
| | | 3.20 | 3.20 | 3.90 | 3.20 | 3.89 | 2.97 | 2.74 | 2.40 | 3.09 |
| 9 | | 4 | 4 | 5 | 4 | 5 | 4 | 3 | 3 | 3 |
| | | 2.47 | 2.63 | 3.89 | 2.40 | 3.66 | 2.40 | 2.40 | 2.40 | 2.63 |
| 10 | | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 2 | 4 |
| | | 2.40 | 2.40 | 3.20 | 2.40 | 3.20 | 2.40 | 2.40 | 1.94 | 3.83 |

* number of feedings per day
** total milk consumed per day (litres)

APPENDIX 3. Cont'd...

| | MOOSE ALFLEX EAR TAG # | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| WEEK | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 |
| 11 | 3<br>2.40 | 3<br>2.40 | 4<br>3.20 | 3<br>2.40 | 4<br>2.86 | 3<br>2.17 | 2<br>1.94 | 2<br>1.60 | 4<br>4.00 |
| 12 | 2<br>1.94 | 2<br>1.83 | 3<br>2.51 | 3<br>2.74 | 3<br>2.69 | 2<br>1.60 | 2<br>1.60 | 2<br>1.60 | 4<br>3.57 |
| 13 | 2<br>1.60 | 2<br>1.84 | 2<br>1.71 | 4<br>3.60 | 4<br>4.00 | 2<br>1.60 | 2<br>1.60 | 2<br>1.60 | 2<br>2.14 |
| 14 | 2<br>1.60 | 2<br>3.00 | 2<br>1.60 | 4<br>4.00 | 4<br>4.00 | 2<br>1.60 | 2<br>1.60 | 1<br>1.03 | 0<br>WEAN |
| 15 | 2<br>1.60 | 3<br>3.26 | 2<br>1.60 | 4<br>3.71 | 4<br>3.57 | 2<br>1.49 | 0<br>WEAN | 0<br>WEAN | |
| 16 | 0<br>WEAN | 2<br>2.43 | 0<br>WEAN | 2<br>2.00 | 2<br>2.14 | 0<br>WEAN | | | |
| 17 | | 0<br>WEAN | | 0<br>WEAN | 0<br>WEAN | | | | |

APPENDIX 3. Cont'd...

| | WAPITI ALFLEX EAR TAG # | | | | | | |
|---|---|---|---|---|---|---|---|
| | 03 | 06 | 30 | 36 | 38 | 39 | 40 |
| WEEK | | | | | | | |
| 1 | *5<br>**0.80 | 6<br>1.81 | 5<br>1.20 | 5<br>2.45 | 5<br>1.86 | 5<br>2.21 | 5<br>1.93 |
| 2 | 5<br>1.84 | 6<br>2.74 | 5<br>2.86 | 5<br>2.83 | 5<br>2.99 | 5<br>2.75 | 5<br>2.86 |
| 3 | 4<br>2.49 | 6<br>2.93 | 5<br>3.14 | 5<br>3.61 | 5<br>3.65 | 5<br>3.48 | 5<br>2.91 |
| 4 | 4<br>2.86 | 5<br>3.40 | 5<br>3.29 | 5<br>3.67 | 5<br>3.85 | 5<br>3.31 | 4<br>3.40 |
| 5 | 3<br>2.40 | 5<br>4.00 | 4<br>3.29 | 4<br>3.31 | 4<br>3.31 | 4<br>3.31 | 4<br>3.20 |
| 6 | 3<br>2.29 | 5<br>4.00 | 4<br>3.09 | 4<br>3.20 | 4<br>2.97 | 4<br>3.20 | 4<br>2.77 |
| 7 | 3<br>1.94 | 4<br>3.45 | 4<br>2.85 | 4<br>2.86 | 4<br>2.69 | 4<br>2.74 | 4<br>2.91 |
| 8 | 2<br>1.60 | 4<br>3.20 | 4<br>3.14 | 4<br>3.14 | 4<br>3.14 | 4<br>3.14 | 4<br>4.00 |
| 9 | 2<br>1.60 | 4<br>2.74 | 4<br>4.00 | 4<br>4.00 | 4<br>4.00 | 4<br>4.00 | 4<br>4.00 |

* number of feedings per day
** total milk consumed per day (litres)

APPENDIX 3. Cont'd...

WAPITI ALFLEX EAR TAG #

| WEEK | 03 | 06 | 30 | 36 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|
| 10 | 2<br>1.60 | 3<br>2.40 | 4<br>3.91 | 4<br>3.67 | 4<br>3.61 | 4<br>3.86 | 3<br>3.00 |
| 11 | 0<br>WEAN | 3<br>2.40 | 3<br>2.71 | 3<br>2.71 | 3<br>2.71 | 3<br>2.71 | 1<br>1.43 |
| 12 | 0<br>WEAN | 2<br>1.94 | 1<br>1.29 | 1<br>1.29 | 1<br>1.29 | 1<br>1.29 | 0<br>WEAN |
| 13 | | 4<br>2.46 | 0<br>WEAN | 0<br>WEAN | 0<br>WEAN | 0<br>WEAN | |
| 14 | | 4<br>4.00 | | | | | |
| 15 | | 4<br>4.00 | | | | | |
| 16 | | 3<br>3.00 | | | | | |
| 17 | | 1<br>1.43 | | | | | |
| 18 | | 0<br>WEAN | | | | | |

APPENDIX 4. Percent relative forage density of rumen samples of wapiti, moose and deer from Elk Island National Park.

WAPITI FIELD ID #

| FORAGE | 10 | 13 | 14 | 41 | 50 | 51 | 53 | 54 | 59 | 60 | 75 | 77 | 78 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AGROPYRON | -- | -- | -- | 2 | -- | -- | -- | -- | 2 | -- | -- | -- | -- | -- |
| AGROSTIS | 2 | | | | | | 2 | | | | | | | |
| BROMUS | 2 | 4 | 6 | | 2 | 2 | | | | 4 | 7 | | | |
| CAREX | 12 | 8 | 4 | 2 | 6 | 7 | | 2 | 2 | 21 | 15 | 8 | 5 | 12 |
| GRASS SEED | | | | | | | | | 2 | | | | 2 | |
| POA | 4 | 2 | | 5 | 2 | 5 | | | 2 | 4 | 7 | 2 | 2 | |
| AMALANCHIER | | | | | | 5 | | | | | | | 2 | |
| BORIGINACEAE | | | | | | 2 | | | | | | | | |
| CERASTIUM | | | 2 | | | | | | | | | | | |
| COMPOSITE | | 2 | | | | | | | | | | | | |
| CORNUS | | | 2 | 2 | 2 | | 7 | | | | | | | |
| Corylus cornuta | 12 | 10 | 11 | 12 | 4 | 2 | 9 | 2 | 10 | 6 | 7 | 4 | 7 | 9 |
| EQUISETUM | 4 | 8 | 4 | 5 | 4 | 9 | 16 | 14 | 4 | | 7 | | | 2 |
| FLOWER | 6 | 12 | 15 | 10 | 34 | 29 | 14 | 27 | 19 | 19 | 10 | 9 | 15 | 2 |
| JUNIPER | 2 | | | | | | | | | | | | | |
| LARIX | 2 | | | | | 2 | | | | | | | | |
| LICHEN | 2 | 2 | 2 | 2 | | | | 2 | 6 | | | 13 | 10 | 2 |
| POPULUS | 21 | 6 | 34 | 27 | 28 | 17 | 30 | 34 | 25 | 24 | 18 | 27 | 26 | 17 |
| RUBUS CHAMAE. | 2 | | | | | | | | | | | | | |
| RUBUS STRIGO. | 12 | 4 | 8 | 12 | 8 | 5 | 4 | 4 | 6 | 4 | | 11 | | |
| SALIX sp. | | 11 | 2 | 12 | 2 | | 4 | 7 | 4 | 6 | 2 | 4 | 7 | 2 |
| SHEPHERDIA CAN | 4 | | | | 2 | | | | | | 2 | 2 | | |
| SOLIDAGO | 2 | | | | | 2 | 2 | | | | 2 | | | |
| UNK. BARK | 8 | 25 | 10 | 5 | 4 | 12 | 9 | 4 | 12 | 9 | 15 | | 23 | 38 |
| UNK. FORB | | | | | | | | | 2 | 2 | | 14 | | |

NB: Microhistological analysis conducted by Composition Analysis Laboratory Range Science Department, Fort Collins, Colorado, U.S.A.

APPENDIX 4. Cont'd...

| | MOOSE FIELD ID # | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16 | 17 | 19 | 20 | 28 | 29 | 37 | 39 | 44 | 45 |
| SPECIES | | | | | | | | | | |
| % | | | | | | | | | | |
| BROMUS | 2 | 2 | | | | | | | | |
| CAREX | 5 | 2 | 2 | | | | | | | |
| UNK. GRASS | | 2 | | | | | | | | |
| AMALANCHIER | | | | | | | | | | |
| BARK | 9 | 2 | | | | | | | | |
| C. CORNUTA | 14 | 17 | 8 | 15 | 2 | 5 | 3 | 9 | 3 | 18 |
| LICHEN | 2 | | | | | 5 | | 1 | | |
| POPULUS | 5 | 12 | | | | | | | | |
| ROSA | | 2 | | | | | | | | |
| RUBUS STRIG. | 2 | | | | | | 3 | | | |
| SALIX | 41 | 44 | 81 | 74 | 91 | 84 | 85 | 84 | 91 | 73 |
| SHEPERDIA CAN. | | 2 | | 2 | | | | | | |
| UNK. BARK | 20 | 14 | 8 | 9 | 6 | 6 | 9 | 4 | 5 | 9 |

APPENDIX 4. Cont'd...

| | DEER FIELD ID # | | | | |
|---|---|---|---|---|---|
| SPECIES % | 3 | 4 | 11 | 12 | 13 |
| CAREX | | | | 6 | 6 |
| POA | | | | | 2 |
| STIPA | 1 | | | | |
| AMALANCHIER | | | | 2 | |
| AMALANCHIER BARK | 1 | 4 | 2 | 8 | 4 |
| CORNUS | 69 | 18 | 47 | 6 | 14 |
| C. CORNUTA | 3 | 21 | 10 | 17 | 29 |
| FERN | | | | 4 | 16 |
| FLOWER | | 2 | | | 4 |
| LINNAEA | 8 | 2 | 2 | 2 | |
| POPULUS | 4 | 6 | 14 | 15 | 6 |
| RUBUS STRIG. | 1 | 16 | 3 | 8 | 2 |
| SALIX sp. | 6 | 18 | 5 | 13 | 8 |
| SHEHERDIA CAN. | | 4 | | | |
| SOLIDAGO | 4 | 8 | 7 | 6 | 4 |
| UNK. BARK | 1 | 2 | 10 | 13 | 4 |
| UNK. BARK | | | | | 2 |

APPENDIX 5. Carcass condition indices, blood and urine characteristics of moose, wapiti and white-tailed deer from Elk Island National Park

| | | BACKFAT | SE | LKFI | SE | FFAT | SE | JFAT | SE |
|---|---|---|---|---|---|---|---|---|---|
| WAPITI | ADF | 20.5 | 4.9 | 216 | 30.0 | 89.2 | 3.2 | 54.9 | 2.9 |
| | ADM | 0.8 | 6.3 | 123 | 39.0 | 85.3 | 4.1 | 57.2 | 3.7 |
| | YLY | 1.0 | 7.7 | 159 | 48.0 | 87.0 | 5.1 | 63.0 | 4.5 |
| | YOY | 0.0 | 7.7 | 140 | 48.0 | 81.0 | 5.1 | 56.5 | 4.5 |
| MOOSE | ADF | 20.6 | 4.6 | 220 | 28.6 | 87.4 | 3.0 | 74.5 | 2.7 |
| | ADM | - | - | - | - | - | - | - | - |
| | YLY | 1.0 | 11.0 | 137 | 67.9 | 86.0 | 7.2 | 68.0 | 6.4 |
| | YOY | 0.0 | 5.6 | 118 | 34.6 | 40.3 | 3.7 | 51.4 | 3.2 |
| DEER | ADF | 19.5 | 7.7 | 211 | 48.0 | 96.0 | 5.1 | 78.0 | 6.4 |
| | ADM | 16.0 | 11.0 | 250 | 67.9 | 95.0 | 7.2 | 83.0 | 6.4 |
| | YLY | 16.0 | 11.0 | 364 | 67.9 | 93.0 | 7.2 | 100.0 | 6.4 |
| | YOY | 1.0 | 11.0 | 192 | 67.9 | 83.0 | 7.2 | 57.0 | 6.4 |

| | | RCP | SE | FCP | SE | BU | SE | U/C | SE |
|---|---|---|---|---|---|---|---|---|---|
| WAPITI | ADF | 12.1 | .31 | 10.1 | .37 | 5.2 | .41 | 3.8 | .64 |
| | ADM | 10.6 | .31 | 9.9 | .47 | 4.4 | .45 | 2.6 | .86 |
| | YLY | 11.8 | .47 | 9.6 | .58 | 3.9 | .56 | 0.52 | 1.2 |
| | YOY | 13.8 | .67 | 10.7 | .58 | 5.7 | .56 | 4.7 | .86 |
| MOOSE | ADF | 10.2 | .31 | 7.4 | .34 | 1.1 | .40 | 1.0 | .64 |
| | YLY | 9.9 | .67 | 6.4 | .82 | 2.1 | .79 | 0.72 | 1.2 |
| | YOY | 10.7 | .41 | 7.1 | .41 | 1.5 | .40 | 2.7 | .64 |
| DEER | ADF | 15.3 | .47 | 13.3 | .58 | 3.7 | .56 | 3.7 | 1.2 |
| | ADM | 15.8 | .67 | 15.4 | .82 | 5.0 | .79 | 10.9 | 1.2 |
| | YLY | 17.1 | .67 | 17.6 | .82 | - | - | 2.9 | 1.2 |
| | YOY | 15.2 | .67 | 15.1 | .82 | 7.1 | .79 | 9.7 | 1.2 |

ADF = adult female
ADM = adult male
YLY = yearling
YOY = young of year

Backfat = subcutaneous fat in coxygeal area (mm)
LKI = left kidney fat index
FFAT= % femur marrow fat

APPENDIX 5 Cont'd.....

JFAT = % jaw marrow fat
RCP = % rumen crude protein
FCP = % fecal crude protein
BU = blood urea nitrogen(mmol/l)
U/C = urinary urea:creatinine ratio

---

APPENDIX 6. Urinary mineral, creatinine and urea excretion (millimoles/day) of penned wapiti and moose calves.

WAPITI

| GROUP | MONTH | Na | K | Ca | P | C | UREA |
|---|---|---|---|---|---|---|---|
| HP | DEC | 368.2 | 323.2 | 2.9 | 5.8 | 30.0 | 915.7 |
| | | *48.1 | 38.2 | 2.1 | 6.0 | 1.6 | 59.1 |
| LP | DEC | 189.3 | 246.9 | 1.3 | 3.2 | 24.8 | 704.2 |
| | | 76.1 | 60.4 | 3.3 | 9.5 | 2.6 | 93.4 |
| HP | JAN | 470.0 | 308.0 | 7.2 | 16.0 | 38.5 | 1633.3 |
| | | 68.0 | 54.0 | 3.0 | 8.5 | 2.3 | 83.5 |
| LP | JAN | 356.5 | 206.1 | 18.2 | 39.3 | 27.6 | 436.0 |
| | | 58.9 | 46.7 | 2.5 | 7.3 | 2.0 | 72.4 |
| HP | FEB | 273.4 | 242.5 | 1.3 | 23.5 | 29.2 | 999.0 |
| | | 68.0 | 54.0 | 2.9 | 8.5 | 2.3 | 83.6 |
| LP | FEB | 95.7 | 76.1 | 2.5 | 10.7 | 30.7 | 471.4 |
| | | 58.9 | 46.7 | 2.5 | 7.3 | 2.0 | 72.4 |
| HP | MAR | 372.2 | 296.9 | 5.9 | 5.5 | 35.6 | 1042.0 |
| | | 68.0 | 53.9 | 2.9 | 8.5 | 2.3 | 83.5 |
| LP | MAR | 368.7 | 233.0 | 4.7 | 2.5 | 22.9 | 382.5 |
| | | 58.9 | 46.7 | 2.6 | 7.3 | 2.0 | 72.4 |

* SE

MOOSE

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HP | DEC | 397.1 | 948.7 | 18.1 | 3.9 | 39.8 | 1573.1 |
| LP | DEC | 378.6 | 743.2 | 24.3 | 3.7 | 34.7 | 1457.5 |
| HP | JAN | 505.4 | 791.2 | 23.5 | 4.2 | 44.0 | 2058.9 |
| LP | JAN | 539.5 | 617.2 | 33.9 | 7.2 | 33.1 | 691.2 |
| HP | FEB | 321.6 | 691.4 | 25.3 | 3.9 | 37.8 | 2220.1 |
| LP | FEB | 246.2 | 165.4 | 12.2 | 2.8 | 33.3 | 829.4 |
| HP | MAR | 148.8 | 649.3 | 42.8 | 3.0 | 44.0 | 1919.7 |
| LP | MAR | 625.5 | 1022.0 | 36.1 | 9.0 | 36.7 | 2232.5 |
| SE | | 77.3 | 110.8 | 6.1 | 0.9 | 2.8 | 202.7 |

APPENDIX 7. Crude protein, fibre, trace minerals and gross energy of forages from Elk Island National Park.

| DATE | SPECIES | CP | NDF | ADF | LIGNIN | K % | P % | Na % | Ca | GROSS ENERGY kJ/g |
|---|---|---|---|---|---|---|---|---|---|---|
| 121189 | HAZEL | 6.0 | 45.3 | 35.4 | 17.1 | 1.42 | .10 | .02 | .89 | 19.1 |
| 281289 | HAZEL | 6.4 | 57.7 | 42.5 | 14.7 | .59 | .14 | .02 | .89 | 19.1 |
| 281289 | HAZEL | 5.8 | 56.7 | 42.5 | 16.3 | .31 | .13 | .02 | 1.1 | 18.7 |
| 060190 | HAZEL | 5.3 | 68.5 | 49.5 | 16.9 | .30 | .10 | .02 | .65 | 18.9 |
| 160190 | HAZEL | 5.1 | 58.9 | 45.2 | 16.8 | .66 | .23 | .02 | .85 | 18.3 |
| 270290 | HAZEL | 5.3 | 65.0 | 50.7 | 19.0 | .59 | .10 | .01 | .68 | 18.4 |
| 100390 | HAZEL | 5.6 | 65.2 | 51.4 | 19.2 | .58 | .13 | .04 | 3.3 | 18.9 |
| 100390 | HAZEL | 6.1 | 62.0 | 47.6 | 18.5 | .65 | .15 | .01 | .80 | 19.2 |
| 100390 | HAZEL | 5.6 | 59.0 | 45.1 | 17.3 | .62 | .14 | .02 | .94 | 19.0 |
| 060190 | GRASSMIX | 11.5 | 53.7 | 50.7 | 27.1 | .62 | .02 | .02 | .82 | 18.4 |
| 160190 | GOLDENROD | 5.0 | 71.9 | 52.0 | 11.1 | 1.9 | .30 | .04 | 1.4 | 18.4 |
| 070190 | WILLOW | 5.7 | 66.2 | 52.5 | 19.2 | .30 | .10 | .01 | .86 | 19.7 |
| 030290 | WILLOW | 5.9 | 54.7 | 42.4 | 15.1 | .52 | .16 | .04 | .80 | 20.2 |
| 180290 | WILLOW | 4.6 | 69.9 | 56.5 | 17.6 | .59 | .11 | .01 | .40 | 18.8 |
| 270290 | WILLOW | 6.0 | 59.8 | 47.8 | 18.2 | .53 | .10 | .02 | .36 | 20.4 |
| 100390 | WILLOW | 7.4 | 49.6 | 40.1 | 19.0 | .39 | .19 | .01 | 3.1 | 21.3 |
| 100390 | WILLOW | 7.1 | 52.2 | 41.6 | 19.3 | .32 | .17 | .02 | .75 | 21.2 |
| 100390 | WILLOW | 7.0 | 54.5 | 44.0 | 18.8 | .43 | .20 | .01 | .80 | 20.9 |
| 150690 | WILLOW LV | 20.0 | | | | | | | | |
| 150690 | WILLOW ST | 9.0 | | | | | | | | |
| 060190 | ASPEN | 7.8 | 53.5 | 41.2 | 16.8 | .30 | .14 | .01 | .92 | 20.1 |
| 160190 | ASPEN | 8.9 | 52.7 | 41.0 | 15.5 | 1.1 | .21 | .06 | .73 | 19.9 |
| 180290 | ASPEN | 5.5 | 61.6 | 48.8 | 14.8 | .26 | .13 | .01 | .56 | 19.1 |
| 270290 | ASPEN | 8.6 | 55.5 | 43.5 | 15.7 | .57 | .17 | .01 | .51 | 20.1 |
| 100390 | ASPEN | 7.0 | 56.2 | 43.2 | 17.0 | .77 | .24 | .01 | 3.3 | 20.6 |
| 100390 | ASPEN | 5.7 | 59.9 | 46.4 | 16.4 | .54 | .20 | .01 | 3.4 | 20.5 |
| 100390 | ASPEN | 7.4 | 56.9 | 44.2 | 17.6 | .57 | .23 | .01 | 3.8 | 20.7 |
| 150690 | ASPEN LV | 15.0 | | | | | | | | |
| 150690 | ASPEN ST | 5.4 | | | | | | | | |
| 110190 | FORB | 5.6 | 62.8 | 45.2 | 10.3 | 2.0 | .37 | .03 | 1.5 | 18.1 |
| 110190 | FORB | 3.6 | 71.0 | 51.0 | 10.3 | 1.3 | .16 | .05 | 1.2 | 18.2 |
| 030290 | POPLAR | 7.6 | 45.3 | 35.6 | 16.3 | .57 | .15 | .01 | .79 | 20.7 |
| 150690 | POPLAR LV | 16.4 | | | | | | | | |
| 150690 | POPLAR ST | 19.0 | | | | | | | | |

lv = green leaves
st = green stems

Appendix 8. Monthly urinary mineral ratios to creatinine from urine deposited on snow from wild wapiti and moose from Elk Island National Park.

| | Na/C | | K/C | | Ca/C | | P/C | |
|---|---|---|---|---|---|---|---|---|
| | W | M | W | M | W | M | W | M |
| NOV | 9.17 | 15.48 | *10.48 | 6.24 | 2.21 | 7.72 | .08 | .19 |
| DEC | 13.18 | - | 7.38 | - | 2.27 | - | .21 | - |
| JAN | 8.95 | 14.73 | 3.99 | 7.38 | 3.57 | 7.48 | .08 | .15 |
| FEB | 16.75 | 11.51 | *15.90 | 7.71 | 3.46 | 8.80 | .19 | .15 |
| APR | 11.28 | 20.82 | 4.84 | 4.41 | 3.15 | 7.80 | .07 | .19 |

* Student-Newman-Keuwls means significantly different between months at alpha = 0.05

W = wapiti
M = moose

Na/C = sodium:creatinine
K/C = potassium: creatinine
Ca/C = calcium:creatinine
P/C = phosphorous:creatinine

Appendix 9. Age and gender differences in urinary mineral ratios to creatinine obtained from urine deposited on snow by wild wapiti and moose from Elk Island National Park

| AGE/GENDER | Na/C | | K/C | | CA/C | | P/C | |
|---|---|---|---|---|---|---|---|---|
| | W | M | W | M | W | M | W | M |
| ADULT FEMALE | 10.69 | 12.78 | 7.14 | 7.11 | 3.04 | 6.31 | 0.15 | 0.16 |
| ADULT MALE | 7.05 | 14.66 | 3.22 | 2.90 | 3.40 | 7.11 | 0.11 | 0.13 |
| YEARLING | 17.29 | 14.82 | *14.34 | 5.70 | 3.25 | - | 0.06 | 0.15 |
| YOUNG OF YEAR | *26.42 | *21.89 | *26.69 | 9.18 | *4.90 | 8.85 | 0.14 | *0.19 |

Student-Newman-Keuwls means significantly different among age/gender classes at alpha = 0.05

W= wapiti
M= moose

B46014